**Premium Motor Spirit Consumption and Environmental Sustainability in Nigeria: A Complex Interplay**

**Abstract**

Anthropogenic activities globally have resulted in environmental degradation, which poses a threat to resource sustainability for the benefit of future generations. Intergovernmental and private organizations have championed the concept of environmental sustainability as a strategy to preserve the environment for intergenerational use. This research employed the Autoregressive Distributed Lag or Bounds Test to Co-integration model, incorporating disaggregated energy consumption sources – petroleum motor spirit and hydroelectricity – along with population growth, to investigate the progress of environmental sustainability efforts in Nigeria. The findings indicate that PMS consumption and population growth consumption patterns constitute a significant threat to environmental sustainability in Nigeria, both in the long and short term, whereas hydroelectricity consumption enhances environmental sustainability. Policy developers are advised to regularly review and update comprehensive programs that promote the widespread adoption and utilization of renewable energy consumption as a dominant component in the energy mix.

**Key words: Premium Motor Spirit, Environmental sustainability, population growth rate and hydroelectricity**

1. **Introduction**

Nigeria, a rapidly developing country with a growing population, faces the dual challenge of meeting its increasing energy needs while protecting its environment. Despite being endowed with abundant energy resources, Nigeria has been struggling with energy poverty in its pursuit of individual and national economic goals. According to the Nigerian Upstream Petroleum Regulatory Commission's Report, Nigeria has recorded a combined reserve of 37.5 billion barrels of crude oil and condensate, solidifying its position as the second largest in Africa and the tenth largest in the world (Villar, 2023). Unfortunately, Nigeria continues to grapple with significant obstacles in the production and distribution of premium motor spirit and power to its burgeoning population. This energy scarcity has compelled the ambitious population to resort to poor-quality energy sources to power their daily economic activities, leading to negative environmental consequences such as land degradation and climate change (Nwozor et al., 2019).

Fossil fuel consumption in Nigeria and other parts of the world is a major contributor to greenhouse gas emissions, primarily carbon dioxide. These emissions are a significant driver of global climate change, leading to rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events. Nigeria is already grappling with the consequences of climate change, including desertification, flooding, and coastal erosion. In August 2012, Nigeria experienced its most severe floods in four decades, affecting 7 million people across 33 states, and an estimated 2 million victims losing their homes due to the elevated floodwaters. The 2012 Niger Delta floods, linked to climate change, caused widespread destruction to house, farmland, crops, and property, as well as loss of life (Hassan et al., 2020). Furthermore, in 2014, a windstorm in the southwest region of Nigeria was reported to have demolished approximately 5,000 houses across four states, according to the National Emergency Management Agency. These unintended negative environmental impacts have prompted government interventions focused on environmental sustainability.

Nigeria, endowed with abundant energy resources, has chosen to prioritize the global agenda of environmental sustainability and climate change, even though this decision carries social and economic implications for the country. The Nigerian government has domesticated international agreements, enacted domestic legislation, implemented policies, and introduced stricter regulations to realize this goal. However, this decision could cause the abundant natural resources such oil and gas to remain stranded and economic waste. Additionally, the development and enforcement of environmental regulations require huge financial burden on individuals, legal entities and government (Kalagbor et al., 2022).

Despite various government efforts towards achieving environmental sustainability, one of the challenges lies in understanding the intricate relationship among Premium Motor Spirit consumption, population growth and environmental degradation. This study seeks to unravel their complex relationship and assess the effectiveness of policy implementations such as renewable energy consumption for achieving sustainable energy future.

Nigeria has a rapidly growing population which has impact on the consumption of premium motor spirit and other form of energy. The populace and the need to commute across locations cause a high demand for transportation which increase the number of vehicles nationwide. This, in turn, exacerbates traffic congestion, causing idling vehicles that further drive-up PMS demand. Furthermore, a larger population corresponds with heightened demand for goods and services, requiring more freight transportation that heavily relies on PMS-powered trucks, further contributing to overall PMS consumption (Pooladsanj et al., 2023).

Consumers are primarily interested in the services that energy enables, such as refrigeration, hot water, air conditioning, and powering machines and computers. Energy consumption is the main factor in the operating costs of most devices (Das et al., 2022). This is a major concern for consumers, as the raw energy units cannot be directly used. However, in areas with low energy costs, the focus on energy usage and efficiency decreases. (Kim et al., 2023)

The substantial portion of Nigeria's economy that operates within the informal sector often relies on small-scale transportation modes, such as motorcycles and tricycles, which primarily utilize PMS (Aliyu et al., 2020). Involvement in myriad economic activities increase the income levels of the upsurging population causing speedy rise in vehicle ownership and corresponding increase in PMS consumption. Many Nigerians are using old and less efficient appliances and vehicles which constitute continuous increase in PMS consumption ( Nsoke et al., 2021). The heavy dependence on PMS consumption has since become a major source of concern as it greatly impacts the environment in areas such as air pollution and environmental degradation. This paper assesses the interconnectivity between PMS consumption and environmental sustainability agenda in Nigeria while capturing additional variables such as population growth and renewable energy consumption entire ecosystem of the model.

1. **Review of Literature**

The Environmental Kuznets Curve analysis originates from the inverted U-shape curve developed by Kuznets in 1955. This was initially meant to analyse the correlation between per capital income and income inequality but consequently gain prominence when it was applied in the analysis of environmental issues (Zhi et al., 2023). The theory was subsequently applied in testing the hypothesis on the impact of economic growth on the environment as noted by Panayotou (Şentürk et al., 2020). The EKC is typically shown in stages as shown below:



 Figure 1: Environmental Kuznets Curve

The outcome of research carried out by economist Simon Kuznets in the 1950s and 1960s set the premise for understanding the linkage between economic growth and environment. They clarify that as a country develops, the environment initially records high level of degradation to a threshold, thereafter, the pollution starts to decline (Zhi et al., 2023).

The three stages of Environmental Kuznets Curve Analysis comprise of the pre-industrial economy which is characterized by abundant natural resources but less waste. The second stage is the industrial economy marks by diminishing natural resources increasing pollution and reducing ecosystem regeneration, ineffective environmental regulations and insufficient conservation financing. And the post-industrial economy is characterized by advancement in technology, provision of industrial services, effective compliance with environmental regulations resulting to an improved environmental condition (Zhang et al., 2022). The post-industrial economic stage demonstrates the institutionalization of rising income levels, high capacity to reduce pollution via the utilization of awareness strategy causing the adoption of cleaner technology that guarantees an environment with good condition.

The application of the theory is not generic for all nations. The outcome of a study carried out by Ficko & Bončina (2018) revealed that CO2 emission have increased and later fall in advanced nations like Japan and United States which is linked to the dynamism of market and economic structure such as income distribution, urbanization, infrastructure rather than sacrifices for environmental preservation. Considering the nature of fluctuating pollution of traditional pollutants such as sulphur, the theory does not apply to greenhouse gas emissions (Pham et al., 2020).

Criticisms of Environmental Kuznets Curve (EKC)

Environmental Kuznets Curve lacks global applicability, as there may not be a genuine overall decrease in pollution worldwide (Carson, 2009). Affluent nations often outsource highly polluting industries, such as clothing and furniture manufacturing, to less developed countries still undergoing industrialization (Wang et al., 2014). This implies that as underdeveloped countries progress, they may face a lack of suitable destinations to offload their environmental contaminants. The effort to clean the environment while growing the economy cannot continue indefinitely, as there may not be enough places to dispose of waste and polluting activities (Ogunbiyi et al., 2020). Grossman and Krueger, who provided the first clear evidence that economic growth is accompanied by improved environmental quality, referred to the Kuznets curve, noting the lack of "empirical support for the notion that environmental quality consistently declines as the economy expands."

The discharge of carbon emissions contradicts the EKC because most pollutants, such as lead and sulphur, are location-specific in their impacts, leading to greater incentive and faster action regarding those specific types of pollution (Stern, 2014). This may work for a nation improving as a whole, where the small benefit of removing these pollutants directly improves people's lives, but significant effects do not stem from reducing carbon dioxide emissions in a local area. This is a tragedy of the commons, where the best strategy is for everyone to pollute and no one to clean up, resulting in the worst outcome for all participants (Rashid, 2024).

Scholars disagree on the long-term shape of the curve stating that as the "inverse U" as a more "N" shape, where pollution increases with growth, declines after a GDP threshold is reached, and then increases again as national wealth rises further (Bertinelli et al., 2011). Although disputed, these findings highlight the question of whether pollution actually declines steadily as a nation's wealth reaches a certain level, or if it merely shifts to poorer developing countries. Levinson concludes that the environmental Kuznets curve alone is an insufficient basis for either a no-action or government-action pollution policy.

Myriad of empirical works exist on the nexus between energy use and the environment. Lau et al. (2023) employed an ARDL model to examine the relationship between the Green Quality Index, which is related to energy use, and carbon dioxide emissions in the United States from 1970 to 2021. Their findings indicate that GDP per capita and urban population are positively associated with CO2 emissions in both the short and long run. Nguyen et al. (2023) considered the effect of natural resource extraction along with energy use on environmental sustainability, utilizing quantile regression and fixed OLS methods. Their analysis of ASEAN countries from 2006 to 2020 revealed that natural resource rent is strongly and positively linked to carbon emissions, making it a significant determinant of environmental pollution.

Achuo et al. (2022) investigated the impact of energy use on environmental degradation, focusing on greenhouse gas emissions and the contribution of natural resources. Using panel data from 173 countries between 1996 and 2020, they employed robust methods and fixed-effect regression models with the Driscoll-Kraay approach. Their key findings suggest that the application of renewable energy enhances environmental quality by reducing greenhouse gas emissions, and the emissions causing the greenhouse effect were from non-renewable sources.

Kelly and Radler (2024) modeled the influence of energy use on climate change across African countries from 2004 to 2019. The authors utilized the Driscoll and Kraay estimation method and the Generalized Method of Moments analysis on existing data. Their findings indicate that Fossil Energy Consumption and Energy Depletion are significant positive drivers of Climate Change. Conversely, the results indicate a lack of support for the Environmental Kuznets Curve hypothesis, with no significant link between real GDP and renewable energy or forestry, and an increase in renewable energy use accompanied by a loss in forest reserves due to urban population development. Asongu et al. (2020) surprisingly discovered that pollutant emissions, electricity consumption, and economic growth are mutually influential, but total natural resources rent only affects pollution in one direction.

Similarly, Ibrahim and Cudjoe (2020) employed the Vector Error Correction Model to examine the environmental effects of energy use in Nigeria from 1990 to 2018. Their results show a strong and persistent relationship between Gross Domestic Product and carbon dioxide emissions in Nigeria. Additionally, they found that charcoal consumption has a continued trend to reduce CO2 emissions, while fuel wood consumption may have a long-run positive impact on CO2 emissions. The researchers also established that the use of gas oil impairs CO2 emissions, while the use of natural gas and fuel oil has a deterring

In a study conducted by Schneider (2021) , the author investigated the interconnections among population growth, energy needs, and environmental sustainability in Africa. The researchers selected Nigeria as a representative case and established a comprehensive framework encompassing factors such as total population, energy consumption, per capita income, and the annual CO2 emissions from the power and heating sectors. The study analyzed data from 1971 to 2018, covering a significant time period. The empirical findings indicate a one-way Granger causality running from population to power use, income per capita, and CO2 emissions, with no feedback effect. Additionally, the study reveals a unidirectional relationship from power use to economic growth, supporting the electricity-driven growth hypothesis. Furthermore, power consumption in Nigeria has been identified as a major driver of environmental degradation. However, it is crucial to balance this by providing affordable energy, transitioning from fossil fuels to renewable sources.

Nigeria's economy requires increased energy usage to drive industrialization, despite the resulting harmful carbon dioxide emissions. According to Mesagan, Alimi, and Adebiyi (2018), the Nigerian economy is expected to experience significant real GDP growth, accompanied by substantial increases in the population's ability to access and utilize more energy, including reduced electricity tariffs and increased government transfer spending. A related study by Benard et al. examined the impact of energy use and CO2 emissions on Nigeria's economic growth using an ARDL approach. The study found that energy use and carbon emissions were significant determinants of Nigeria's economic growth in the short run. Similarly, Mesagan, Alimi, and Adebiyi (2018) investigated the impact of energy consumption and population on Nigeria's economic growth from 1970 to 2015 using the ARDL model, and the results suggest that Nigeria's GDP growth is driven by effective energy demand fueled by a large population.

However, Achuo et al. (2022) discovered that renewable energy sources have better environmental impacts from the perspective of developed nations, while non-renewable energy sources negatively affect the environment of developing nations. Additionally, non-renewable energy has diverse impacts on pollution in different locations. Renewable energy sources also have varying environmental impacts depending on the site of implementation. Ultimately, the abundance of natural resources and the strength of institutions will be crucial for environmental sustainability.

The findings of Kelly et.al. (2024) have consistently demonstrated that increases in population, energy consumption, and economic growth have a significant impact on the environment, which also corroborated the outcomes of previous studies. Specifically, fossil energy consumption and energy depletion have a positive and significant effect on climate change. Conversely, the results indicate a lack of support for the Environmental Kuznets Curve hypothesis, with no significant link between real GDP and renewable energy or forestry, and an increase in renewable energy use accompanied by a loss in forest reserves due to urban population development.

Most prior studies considered how population growth influences the use of renewable energy, but none examined the combined impact of renewable and non-renewable energy methods on environmental sustainability, nor focused on specific country. This study aims to address these gaps by investigating the impacts of renewable and non-renewable energy usage on environmental sustainability projects in Nigeria, given the country's rapid increase in dependence on fossil fuel consumption for micro and macro-economic growth.
It is designed to use a single system to fill the research gap by focusing on new disjointed fossil fuel variables - premium motor spirit consumption, along with population growth rate and renewable energy consumption, to assess their respective relationships with the environmental sustainability agenda in Nigeria

1. **Methodology**

This study utilizes the Autoregressive Distributed Lag approach to Cointegration due to its comparative advantages over alternative methods. The model specification begins with the traditional production theory framework. The subsequent equation models CO2 emissions as the dependent variable, with its fluctuating values determined by energy consumption, population growth, and economic expansion.

 …………………………………………………………(1)

Where:

 Ct represents CO2 emissions per capita,

 PMSt represents Premium Motor Spirit consumption per capita as economic improves,

Pt represents Population Growth

Therefore, C02 emission function can be written as:

 ……………………………………..(2)

The theoretical framework of this study is based on the Environmental Kuznets Curve hypothesis, which posits a non-linear relationship between economic growth and environmental degradation. Specifically, a quadratic function can be used to model the link between economic expansion and carbon dioxide emissions. Furthermore, the long-term relationships between CO2 emissions, petroleum, motor spirit consumption, and population growth are considered in the baseline logarithmic estimation model:

Where:

C02 represents per capita CO2 emissions,

 Stands for Premium Motor Spirit consumption per capita

POP represents population growth

REC represents Renewable energy Consumption

 is the error term

From equation (3), is expected to be positive and negative sign is expected for  . Since population expansion increases PMS usage which in turn cause increase in CO2 emissions, and are strongly anticipated to be positive.

This study has three independent variables. These variables are: Premium Motor Spirit Consumption and Population Growth and hydroelectricity consumption which serves as proxy for renewable energy consumption while Carbon emission per capita represents the dependent variable. The data were sourced from the World Bank data base and the International Energy Agency.

This study utilizes the ARDL bounds testing approach to examine the relationship between the primary dependent variable and the primary independent variables. The ARDL framework of the estimation model is as follows:

The estimation method begins with equation 2, and ordinary least squares regression was primarily introduced to enable the Wald test to assess the joint significance of the coefficients associated with the lagged variables. The fundamental objective is to determine the potential for long-term relationships among the variables included in the analysis.

Hereof,  is the null hypothesis and it contains relevant facts on why there is non-existence of co-integrating associations among the included explanatory variables (regressors) and the only dependable variable (regressand). In similar pattern of expression, the alternative hypothesis is derived to be 

As per the established econometric tradition, the F-statistic is presented alongside the upper and lower critical values to provide a basis for drawing substantive conclusions, as observed in Pesaran et al. Consequently, if the F-statistic is found to exceed the upper critical value, it suggests the absence of cointegration, and the null hypothesis should not be accepted. In this economic context, it indicates the presence of a long-term association among the defined and included variables (Arize, 2017). Conversely, when the F-statistic values fall below the lower critical value, the null hypothesis will be readily accepted. If the experiment results show the F-statistic value falling within the range of the lower and upper limits, the test is deemed inconclusive (Merwe, 2021).
Additionally, to determine the initial dynamics of the defined and included variables, as well as the initial adjustment rate towards the long-run outcome, the Error Correction Model was estimated as shown in the equation below.

1. **Results**

**Table 1. Descriptive Statistics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Statistic** | CO2E | PMSC | POPG | REC |
|  Mean | 90.14826 | 9.233237 | 2.595355 | 5.8895 |
|  Median | 92.39355 | 7.663105 | 2.581974 | 5.705 |
|  Maximum | 131.1133 | 21.72304 | 2.764062 | 8.76 |
|  Minimum | 38.85728 | 2.974652 | 2.380007 | 1.86 |
|  Std. Dev. | 26.26345 | 5.760761 | 0.102061 | 1.723058 |
|  Skewness | -0.361917 | 0.80983 | -0.113311 | -0.284359 |
|  Kurtosis | 2.254023 | 2.317032 | 2.06409 | 2.521689 |
|  Jarque-Bera | 1.800697 | 5.149574 | 1.545476 | 0.920369 |
|  Probability | 0.406428 | 0.07617 | 0.461747 | 0.631167 |
|  Sum | 3605.93 | 369.3295 | 103.8142 | 235.58 |
|  Sum Sq. Dev. | 26900.97 | 1294.268 | 0.406242 | 115.7882 |
|  Observations | 40 | 40 | 40 | 40 |

**Source: Researcher’s computation**

Descriptive statistics were employed to ascertain the distribution of the raw data. This study will utilize the Jarque-Bera test, which combines measures of skewness and kurtosis to analyze normality. The Jarque-Bera statistic quantifies the deviation of the series' skewness and kurtosis from the normal distribution. If the p-value of the Jarque-Bera test is less than 0.05, the normality of the distribution is rejected; otherwise, it is accepted (Thadewald & Büning, 2024).

In the present case, all the probability values associated with each Jarque-Bera statistic exceed 0.05, indicating the distributions are normally distributed. Furthermore, the descriptive statistics showed that none of the distributions deviated significantly from the mean.

**Table 2. Unit Root Test**

|  |  |  |
| --- | --- | --- |
| Variables | Level | 1st Difference |
| Constant | Constant with Trend | Constant | Constant with Trend |
| LCO2E | -1.531218 | -2.735503 | -7.199308 | -7.114485 |
| 0.5075 | 0.2288 | 0.0000 (\*\*) | 0.0000 (\*\*) |
|   |   | I (1) | I (1) |
| POPG | -1.866923 | -1.600219 | -6.427500 | -6.964672 |
| 0.3433  | 0.7719 | 0.0001 (\*\*) | 0.0004 (\*\*) |
|  |   | I (1) | I (1) |
| LPMSC | -1.932495 | -2.865281 | -10.07606 | -6.270141 |
| 0.9984 | 0.1843 | 0.0000 (\*\*) | 0.0000 (\*\*) |
|   |   | I (1) | I (1) |
|  LREC | -3.412918 | -3.522628 | -6.945508 | -6.970690 |
| 0.0165(\*\*) | 0.0508(\*\*) | 0.0000 (\*\*) | 0.0000 (\*\*) |
| I(0)  | I(0)   | I (1) | I (1) |

**Source: Researcher’s computation**

All other variables considered are integrated at I(1) while Renewable Energy Consumption as proxied by Hydroelectricity Consumption is integrated at I(0) and I(1) as contained on the unit root results Table 2 above. Following the suggestions of Pesaran et al. (2001) with regard to the estimation of I(1) and I(0) variables, the bound test for the co-integration test is estimated and reported in Table 3.

Table 3: Results of Bound Tests to Co-integration

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | AIC Lag | F-Statistic | Outcome |
| *FCO2E (LCO2E, LREC, PMSC, POPG)* | 3 | 4.988895 | Cointegration |
| *Critical Value Narayan (2005)* | I (0) | I (1) |   |
| 5% | 2.79 | 3.67 |   |

**Source: Researcher’s computation**

The null hypothesis explained the existence of no co-integration against the alternative hypothesis of , which showed that co-integration existed.

Table 3 contains the outcome of calculated F-statistics where individual variables were assigned the position of dependent variables through normalization. Still on the table, *FCO2E (CO2E/LREC, LPMSC, POPG)* represents the F-statistics and has the value 4.9888. The upper bound critical value at 5% significant level is 3.6 (Narayan, 2005). Since the F-statistics is greater than the critical bound, it implies that the null hypothesis which has no co-integration is rejected. The study has also determined the co-integration nexus among the variables which guaranteed the estimation of equation (5).

**Table 4: ARDL Long Run Form and Bounds Test**

The Dependent Variable: D(LCO2E)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient | Std. Error | t-Statistic | Prob.    |
| C | 4.152234 | 1.396524 | 2.973263 | 0.009 |
| LCO2E(-1)\* | -0.773477 | 0.165437 | -4.675365 | 0.0003 |
| LPMSC (-1) | 0.320412 | 0.112095 | 2.85839 | 0.0114 |
| D(LCO2E(-2)) | 0.519729 | 0.172805 | 3.007608 | 0.0083 |
| D(LCO2E (-3)) | 0.398984 | 0.181048 | 2.203745 | 0.0425 |
| D(LPMSC) | 0.480723 | 0.210512 | 2.283593 | 0.0364 |
| D(LPMSC (-3)) | 0.69201 | 0.236857 | 2.921643 | 0.01 |
| D(POPG (-3)) | 1.247562 | 0.498127 | 2.504507 | 0.0235 |
| D(LREC (-2)) | -0.433826 | 0.19645 | -2.208327 | 0.0422 |

**Source: Researcher’s computation**

The analysis in Tables 4 and 5 reveals a statistically significant relationship between Premium Motor Spirit consumption, population growth, and CO2 emissions. Specifically, a unit increase in PMS consumption and population growth is associated with a rise in CO2 emissions in the short term. Conversely, a unit increase in renewable energy consumption tends to reduce CO2 emissions by 4.3% in Nigeria during the same period.

**Table 5: ARDL Error Correction Result (4, 4, 4, 4) based on SIC.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient | Std. Error | t-Statistic | Prob.    |
| D(LCO2E(-2)) | 0.519729 | 0.14336 | 3.625357 | 0.0023 |
| D(LCO2E(-3)) | 0.398984 | 0.152819 | 2.610827 | 0.0189 |
| D(LPMSC) | 0.480723 | 0.162944 | 2.950228 | 0.0094 |
| D(LPMSC(-3)) | 0.69201 | 0.168023 | 4.118548 | 0.0008 |
| D(POPG) | 1.970286 | 0.914218 | 2.15516 | 0.0467 |
| D(POPG(-3)) | 1.247562 | 0.385608 | 3.235313 | 0.0052 |
| D(LREC(-1)) | -0.368917 | 0.1754 | -2.10329 | 0.0516 |
| D(LREC(-2)) | -0.433826 | 0.16086 | -2.69692 | 0.0159 |
| CointEq(-1)\* | -0.773477 | 0.138518 | -5.58396 | 0.0000 |

**Source: Researcher’s computation**

The analysis reveals that alongside the presence of a long-term relationship between the variables, certain changes also emerge. Notably, an Error Correction Mechanism has been incorporated in this research to control and enhance these alterations. This mechanism will reconcile the immediate dynamics embedded in the co-integration functions into a more static arrangement. Furthermore, the speed of correcting deviations from the long-term relationship, or the long-term adjustment, demonstrates that the cointegration coefficient is negative, statistically significant, and the absolute value is less than 1, which is theoretically anticipated. With the coefficient standing at 0.77 and the p-value at 0.000, this result indicates that the deviations are corrected at a rate of 77%.

Table 6 Diagnostic test for ARDL (3,4,1,0)

|  |  |
| --- | --- |
| R-squared | 0.728235 |
| Adjusted R-squared | 0.52441 |
| Breusch-Godfrey Serial Correlation LM Test | 0.099 |
| Heteroskedasticity Test: Breusch-Pagan-Godfrey | 0.2632 |
| Jarque-Bera Normality Test | 0.543402 |

 **Source: Researcher’s computation**

The diagnostic test results are shown in Table, and all tests reveal that the model is stable, has no problem of autocorrelation and has a constant variance. The R2 result shows that the independent variables explain about 0.89% of the dependent variable.

The CUSUM and CUSUM OF SQUARE tests are employed to check how stable each residual is in model. The result is shown below

 Figure: 2 CUSUM GRAPH



Figure: 3 CUSUM of SQUARES GRAPH

The CUSUM and CUSUM of squares tests indicated that the model's residual errors are within the acceptable range, suggesting the model's reliability. This implies that the short-term coefficient is stable and consistent with the long-run relationship. Additionally, the CUSUM and CUSUM-of-squares statistics for the model remained within the 5% significance level, allowing the acceptance of the null hypothesis that all coefficients in the error correction model are stable.

1. Findings

The consumption of Premium Motor Spirit and population growth have been found to be statistically significant factors that impact CO2 emissions in both the long-term and short-term. The positive coefficients associated with PMS consumption in both the short-term and long-term suggest that PMS consumption represents the most negatively influential variable in achieving environmental sustainability goals in Nigeria.

This is synonymous with the pre-industrial and semi-industrial economy era of Environmental Kuznets Curve analysis characterized by abundant natural resources dwindling resources, growing industrial waste, and decreased ecosystem regeneration capacity, leading to higher ecological footprints and pollution, along with lax environmental regulations and limited conservation funding.

The findings suggest that hydroelectricity, a form of renewable energy, has a statistically significant impact on CO2 emissions in Nigeria, both in the short and long term. Specifically, a 1% increase in hydroelectricity consumption is associated with a 4.7% reduction in CO2 emissions over time. This aligns with the research conducted by Opeyemi, which indicates that the utilization of renewable energy can effectively mitigate environmental damage. Furthermore, the outcomes corroborate the findings of Somoye et al., demonstrating that renewable energy consumption protects the environment and preserves finite energy source.

This aligns with post-industrial economy of Environmental Kuznets Curve analysis characterized by structural shifts toward technology-intensive industries and services, coupled with stricter environmental regulations, resulting in reduced environmental deterioration (Zhang et al., 2022). This stage is marked by a shift in economic capacity to mitigate pollution through the adoption of clean technologies, increased societal awareness, and institutional enhancements driven by rising income levels.

1. **Conclusion and Recommendations**

Environmental sustainability has become a critical focus for multinational corporations and global organizations. Researchers across various disciplines have conducted extensive academic investigations to optimize the utilization of environmental resources. Nigeria, as a member of the international community, has participated in discussions and forums aimed at proposing solutions and recommendations to reduce CO2 emissions and enhance global environmental quality. This study examines the relationship between petroleum consumption, renewable energy consumption, population growth, and environmental sustainability in Nigeria. The findings reveal several policy recommendations:

The research suggests that the consumption of Premium Motor Spirit is the most impactful factor hindering Nigeria's progress towards environmental sustainability. This indicates that the current PMS consumption pattern in Nigeria must be reversed to ensure progress towards the attainment of environmental sustainability goals. Therefore, the government should implement a comprehensive PMS consumption reduction policy to mitigate future emissions and safeguard the environment for present and future generations.

Hydroelectricity consumption, which serves as a proxy for renewable energy consumption, was found to have a significant reducing impact on CO2 emissions. This suggests that Nigeria should consistently develop and review policies and programs that promote the rapid production and utilization of energy from renewable sources, aligned with the national goal of attaining environmental sustainability.

In conclusion, this research revealed that the consumption of fossil fuels, such as PMS, and population growth deplete non-renewable resources, reduce environmental quality, and undermine the concept of environmental sustainability. Conversely, the consumption of energy from renewable sources, such as hydroelectricity, improves the quality of the environment in Nigeria. It is essential that Nigeria acquires new and cleaner technologies and channels the revenue from fossil fuels towards the production of renewable energy to further assist in attaining environmental sustainability.

**Recommendations**

Based on the finding that increasing hydroelectric power consumption can reduce CO2 emissions by 4.3% in Nigeria, experts should explore advancements in hydroelectric technology that could further enhance efficiency and mitigate environmental impacts. Additionally, research should investigate the long-term sustainability of hydroelectric projects, considering factors such as climate change, water availability, and maintenance costs.

Furthermore, the findings of this study indicate that population growth significantly impacts CO2 emissions in Nigeria. Future research should focus on identifying strategic population management approaches and examining the role of public behavior and lifestyle choices in CO2 emissions. This would provide a better understanding of how public awareness and behavior modification can contribute to sustainability efforts

**References**

Achuo, E.D., Miamo, C.W. and Nchofoung, T.N. (2022). Energy consumption and environmental sustainability: What lessons for posterity? Energy Reports, 8, 12491–12502.<https://www.researchgate.net/publication/364100425_Energy_consumption_and_environmental_sustainability_What_lessons_for_posterity>

 Aliyu, Y. A., Botai, J. O., Abubakar, A. Z., Youngu, T. T., Sule, J. O., Shebe, M. W., & Bichi, M. A. (2020). Atmospheric Air Pollution in Nigeria: A Correlation between Vehicular Traffic and Criteria Pollutant Levels. In IntechOpen eBooks. IntechOpen. <https://doi.org/10.5772/intechopen.86554>

Arize, A. C. (2017). A convenient method for the estimation of ARDL parameters and test statistics: USA trade balance and real effective exchange rate relation. In International Review of Economics & Finance (Vol. 50, p. 75). Elsevier BV. <https://doi.org/10.1016/j.iref.2017.03.024>

Asongu, S. A., Agboola, M. O., Alola, A. A. and Bekun, F. V. (2020). The Criticality of Growth, Urbanization, Electricity and Fossil Fuel Consumption to Environment Sustainability in Africa. [Science of the Total Environment](https://www.sciencedirect.com/journal/science-of-the-total-environment) [Volume 712](https://www.sciencedirect.com/journal/science-of-the-total-environment/vol/712/suppl/C), 136376. <https://www.sciencedirect.com/science/article/abs/pii/S0048969719363727>

[Bernard](https://www.researchgate.net/profile/Anthony-Bernard-6?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19), A. O.,  [Ezenekwe](https://www.researchgate.net/profile/Uju-Ezenekwe?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19), U. R. and [Uzonwanne](https://www.researchgate.net/profile/Chinecherem-Uzonwanne?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19), C. (2018). Analysis of the Effect of Energy Consumption, CO2 Emission on Economic Growth in Nigeria. Journal of Social Sciences and Education, Volume 1, Issue Number 1, June 2018. <https://www.researchgate.net/publication/341103417_ANALYSIS_OF_THE_EFFECT_OF_ENERGY_CONSUMPTION_CO_2_EMISSION_ON_ECONOMIC_GROWTH_IN_NIGERIA>

 Bertinelli, L., Strobl, E., & Zou, B. (2011). Sustainable economic development and the environment: Theory and evidence. In Energy Economics (Vol. 34, Issue 4, p. 1105). Elsevier BV. <https://doi.org/10.1016/j.eneco.2011.09.007>

 Carson, R. T. (2009). The Environmental Kuznets Curve: Seeking Empirical Regularity and Theoretical Structure. In Review of Environmental Economics and Policy (Vol. 4, Issue 1, p. 3). University of Chicago Press. <https://doi.org/10.1093/reep/rep021>

Das, H., Lin, Y., Agwan, U., Spangher, L., Devonport, A., Yang, Y., Drgoňa, J., Chong, A., Schiavon, S., & Spanos, C. J. (2022). Machine Learning for Smart and Energy-Efficient Buildings. In arXiv (Cornell University). Cornell University. <https://doi.org/10.48550/arXiv.2211>.

 Ficko, A., & Bončina, A. (2018). Public attitudes toward environmental protection in the most developed countries: The Environmental Concern Kuznets Curve theory. In Journal of Environmental Management (Vol. 231, p. 968). Elsevier BV. <https://doi.org/10.1016/j.jenvman.2018.10.087>

Hassan, I., Kalin, R. M., Aladejana, J. A., & White, C. J. (2020). Potential Impacts of Climate Change on Extreme Weather Events in the Niger Delta Part of Nigeria. In Hydrology (Vol. 7, Issue 1, p. 19). Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/hydrology7010019>.

Kalagbor, A. N., Idowu, S. Ο., & Weldmeskel, E. M. (2022). Corporate Social Responsibility (CSR), Service Failures and Recovery Strategies for Sustainable Business: The Case of Nigeria. In Economic Insights – Trends and Challenges (Vol. 2022, Issue 1, p. 1). Oil & Gas University of Ploiești. <https://doi.org/10.51865/eitc.2022.01.01>

Kelly, A. M. & Radler, R. D. N. (2024). Does Energy Consumption Matter for Climate Change in Africa? New Insights from Panel Data Analysis. [Innovation and Green Development](https://www.sciencedirect.com/journal/innovation-and-green-development) Volume 3, Issues 3, 100132<https://www.sciencedirect.com/science/article/pii/S2949753124000092>

Kim, Y. G., Gupta, U., McCrabb, A., Son, Y., Bertacco, V., Brooks, D. J., & Wu, C.-J. (2023). GreenScale: Carbon-Aware Systems for Edge Computing. In arXiv (Cornell University). Cornell University. <https://doi.org/10.48550/arXiv.2304>.

Lau, C. K., Mahalik, M. K., Rather, K. N. & Gozgor, G. (2023). The Impact of Green Quality of the Energy Consumption on Carbon Emissions in The United States. [Economic Analysis and Policy](https://www.sciencedirect.com/journal/economic-analysis-and-policy). Volume 80, pages 850-860 <https://www.sciencedirect.com/science/article/pii/S0313592623002333>

Li, J., Liu, S., Qin, Y., Zhang, Y., Wang, N., & Liu, H. (2020). High-order radiomics features based on T2 FLAIR MRI predict multiple glioma immunohistochemical features: A more precise and personalized gliomas management. In PLoS ONE (Vol. 15, Issue 1). Public Library of Science. <https://doi.org/10.1371/journal.pone.0227703>

Liu, S., Hou, S., He, K., & Yang, W. (2017). L-Kurtosis and its application for fault detection of rolling element bearings. In Measurement (Vol. 116, p. 523). Elsevier BV. <https://doi.org/10.1016/j.measurement.2017.11.049>

 Merwe, S. van der. (2021). On Determining the Distribution of a Goodness-of-Fit Test Statistic. In arXiv (Cornell University). Cornell University. <https://doi.org/10.48550/arXiv.2104>.

Mesagan, P. E., Alimi, O. Y. and Adebiyi, K. A. (2018). Population Growth, Energy Use, Crude Oil Price, and the Nigerian Economy. Economic Studies (Ikonomicheski Izsledvania), 27 (2), p. 115-132.<https://www.iki.bas.bg/Journals/EconomicStudies/2018/2018-2/7_Nigeria-3_f-f.pdf>

Nguyen, T. T. H., Tu, Y., Diep, G. L., Tran, T. K., Nguyen Hoang Tien, N. H., & Chien, F. (2023). Impact of Natural Resources Extraction and Energy Consumption on The Environmental Sustainability in ASEAN Countries. Resource Policy, Volume 85, Part A, 103713. <https://www.sciencedirect.com/science/article/abs/pii/S0301420723004245>

 Nsoke, U. P., Ndu, O. M., & Ofoegbu, G. N. (2021). Accounting Practices and Its Effects on the Growth of Micro and Small Scale Enterprises: Analysis from Nigeria. In Universal Journal of Accounting and Finance (Vol. 9, Issue 4, p. 574). <https://doi.org/10.13189/ujaf.2021.090405>

Nwozor, A., Oshewolo, S., & Ogundele, O. (2019). Energy poverty and environmental sustainability in Nigeria: an exploratory assessment. In IOP Conference Series Earth and Environmental Science (Vol. 331, Issue 1, p. 12033). IOP Publishing. <https://doi.org/10.1088/1755-1315/331/1/012033>

 Ogunbiyi, M. E., Onifade, M. K., Afolabi, O. J., & Oroye, O. A. (2020). An Assessment of Solid Waste Transportation in Ado-Odo/Ota Local Government Area, Ogun State, Nigeria. In Transport and Communications (Vol. 8, Issue 2, p. 23). University of Zulia. <https://doi.org/10.26552/tac.c.2020.2.3>

 Pham, N.-T., Trung-Kien, P., Cao, V. H., Tran, H. G., & Vo, X. V. (2020). The Impact of International Trade on Environmental Quality: Implications for Law. In Asian Journal of Law and Economics (Vol. 11, Issue 1). De Gruyter. <https://doi.org/10.1515/ajle-2020-0001>

 Pooladsanj, M., Savla, K., & Ιωάννου, Π. (2023). Ramp metering to maximize freeway throughput under vehicle safety constraints. In Transportation Research Part C Emerging Technologies (Vol. 154, p. 104267). Elsevier BV. <https://doi.org/10.1016/j.trc.2023.104267>

Rashid, A. (2024). Untitled. https://doi.org/10.55277/researchhub.vq5dnd6h
Stern, D. I. (2014). The Environmental Kuznets Curve: A Primer. In RePEc: Research Papers in Economics. Federal Reserve Bank of St. Louis. <https://doi.org/10.22004/ag.econ.249424>

Schneider, N. (2021). Population growth, electricity demand and environmental sustainability in Nigeria: insights from a vector auto-regressive approach. International Journal of Environmental Studies. [(PDF) Population Growth, Electricity Demand and Environmental Sustainability in Nigeria: Insights from a Vector Auto-Regressive Approach (researchgate.net)](https://www.researchgate.net/publication/350859109_Population_Growth_Electricity_Demand_and_Environmental_Sustainability_in_Nigeria_Insights_from_a_Vector_Auto-Regressive_Approach)

 Şentürk, H., Omay, T., Yıldırım, J., & Köse, N. (2020). Environmental Kuznets Curve: Non-Linear Panel Regression Analysis. In Environmental Modeling & Assessment (Vol. 25, Issue 5, p. 633). Springer Science+Business Media. <https://doi.org/10.1007/s10666-020-09702-0>

Thadewald, T., & Büning, H. (2024). Jarque-Bera test and its competitors for testing normality: A power comparison. <https://www.econstor.eu/bitstream/10419/49919/1/668828234.pdf>

Villar, L. (2023). Country Analysis Brief. <https://www.eia.gov/international/content/analysis/countries_long/Nigeria/nigeria.pdf>

Wang, L., Ding, X., & Wu, X. (2014). Environmental Kuznets curve for pollutants emissions in China’s textile industry: an empirical investigation. In International Journal of Environmental Technology and Management (Vol. 17, Issue 1, p. 14). Inderscience Publishers. <https://doi.org/10.1504/ijetm.2014.059457>

 Zhang, L., Xu, M., Chen, H., Li, Y., & Chen, S. (2022). Globalization, Green Economy and Environmental Challenges: State of the Art Review for Practical Implications. In Frontiers in Environmental Science (Vol. 10). Frontiers Media. <https://doi.org/10.3389/fenvs.2022.870271>

 Zhi, Z., Ding, Z., Geng, Y., Pan, L., & Wang, C. (2023). The impact of digital economy on environmental quality: Evidence from China. In Frontiers in Environmental Science (Vol. 11). Frontiers Media. <https://doi.org/10.3389/fenvs.2023.1120953>

 Zhi, Z., Ding, Z., Geng, Y., Pan, L., & Wang, C. (2023). The impact of digital economy on environmental quality: Evidence from China. In Frontiers in Environmental Science (Vol. 11). Frontiers Media. <https://doi.org/10.3389/fenvs.2023.1120953>