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IMPACT OF HUMAN DEVELOPMENT, REAL OUTPUT AND ENERGY DEPLETION ON CO2 EMISSIONS IN NIGERIA

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Abstract

This study examines the impact of human development, real output and energy depletion on CO2 emissions in Nigeria from the year 1990 to 2022. The paper applied the Autoregressive Distributed Lag technique in the analysis of the specified regression model. The result of the bound test revealed evidence of cointegration between human development, economic growth, energy depletion and CO2 emissions. The findings show that human development and economic growth (RGDP) have mitigating effects on CO2 and significantly improves environmental quality in the long run. In contrast, the study found that in the short run, RGDP and energy depletion exert positive impact on CO2 emissions. The paper therefore recommends the government can take significant steps to improve environmental quality by encouraging the human development of the population. This may contribute to reverse the effect of livelihood activities on the environment.

Keywords: Human Development, HDI, RGDP, Energy Depletion, RGDP

1. Introduction

Investing in human capital and a wide spectrum of energy resources has proven to be the cornerstone of economic prosperity for many countries across the world. In fact, the unprecedented prosperity brought about by the industrial revolution would have been impossible without the dynamic combination of human capital and energy resources. However, while the positive benefits of human development in enhancing productivity and energy use have attracted a growing literature, their influence on the environment are not fully understood.

Historically, the contribution of fossil fuels as an energy source to the manufacturing and transportation sector is unparalleled by any other natural resources. However, according to the report of the Inter-governmental Panel on Climate Change (IPCC), fossil fuels (coal, natural gas and crude oil) are among the largest primary conduit of carbon dioxide to the atmosphere (IPCC, 2005).

The quantity of carbon emission depends on the level of energy use and on the makeup of the energy basket (Henriques & Borowiecki, 2014). Consequently, CO2 emissions could be reduced through dynamic changes in technology that brings about fuel switching devices that are cost efficient and effective with lower levels of emission. Moreover, decline in economic activities and advanced human development could also lead to the fall in the levels of CO2 emissions at a given period of time. The quantity of CO2 emissions would also decline where energy resources as part of the factor endowments of a country have severely depleted. This research investigates the impact of human development, economic growth and energy depletion on CO2 emissions in Nigeria.

The interest in Nigeria is not just because it is the most populous country in Africa and rich in energy resources, the interest is buoyed by the need to uncover the impact of human development and economic growth on the volume of CO2 emissions in the country. A thorough understanding of the impact of human development on CO2 is necessary in the design of effective policies to reduce environmental pollution. Thus, in this regard, several research has been done by scholars across the globe, albeit with different methodologies and results. For instance, Sezgin, et al (2021) using cointegration analysis found that human development has a decreasing impact on CO2 emissions and the direction of causality was not the same for all countries. Similar outcome was obtained by Minh and Ly (2023) in their study on the impact of human development on CO2 emissions in Vietnam. On the other hand, Bieth (2021) observed that human development positively impacted on CO2 emissions.

The influence of economic activities on CO2 emission has also been the focus of studies by many scholars with divergent results. While many of these studies have argued that rising economic activities goes hand in hand with increased levels of CO2 emission especially in the short run time period (Osadume & University, 2021; Olusanya & Musa, 2018; Teklie & Yakmur, 2023;), others suggest that in the short run, economic growth does not have significant impact on CO2 emissions (Espoir, et al., 2023; Musa & Maijama'a, 2020). Moreover, empirical studies also reveal that higher national income levels are favorable to the demand for environmental sustainability and favour reduced pollution levels in the long run (Onofrei, et al., 2022; Li & Haneklaus, 2021).

The present study contributes to these set of studies that analyzed the antecedents of CO2 emissions in two folds: first, the study aims to evaluate the impact of divers of CO2 emission in Nigeria. This is done by verifying the existence of a long run relationship between human development, economic growth, energy depletion and carbon emissions in the country. The second objective is to estimate the specific impact of human development, economic growth and energy depletion on CO2 emissions in Nigeria.

This study is significant as it quantifies the influence of environmental pollution drivers on CO2 emission, as well as reveals evidence of a long run relationship existing between human development, economic growth, energy depletion and CO2 emissions in Nigeria. The rest of the paper is laid out as follows. Section 2 is an exposition on previous scholarly literature on the subject-matter and in Section 3, the methodology of the study is discussed. Result and discussion of findings is in Section 4, while Section 5 concludes the study as well as makes policy

2. Literature Review

2.1 Theoretical Framework

Environmental Kuznets Curve (EKC)Theory

The environmental Kuznets curve theory is one of the foremost theories that connects the influence of human activities with changes in the quality of the environment. The EKC as posited by Grossman and Krueger (1995) asserts that growth in real output could lead to environmental pollution during the developmental phase of a country. However, as the economy expands and per capita income stabilizes, the intensity of the effect of economic activities on the environment may begin to decrease and eventually change. This is because of the possibility of economic development to positively contribute to human development through an expansion in knowledge and the number of educated people who are better able to understand the imperative of a sustainable environment and the need to promote eco-friendly livelihoods. Therefore, with improved human development leading to better understanding of the consequences of environmental pollution, it would engender environmental protection activities that would eventually lead to the decline in CO2 emissions in the long run.

2.2 Empirical Review

There are dozens of empirical literatures that have examined how drivers of environmental pollution impact on CO2 emissions. However, this review of related works on the impact of human development, real output and energy depletion on CO2 emissions concentrates on three strands; the first is on the impact of human development on environmental pollution; while the second is on relationship between economic growth and CO2 emissions. The third strand reviews related works on energy depletion and carbon emissions.

Accordingly, on the first strand, Bano, et al (2018) studied the impact of human capital on carbon emissions in Pakistan. The scope of the study was from 1971 to 2014 and the study employed the autoregressive distributed lag (ARDL) approach in the estimation of the specified model. The findings revealed the existence of long run relationship between human capital and economic growth. Moreover, the study found that improvement in human capital through education reduces the quantity of carbon dioxide emissions. In addition, the study observed a bidirectional causality between human capital and CO2 emissions in the long run, which was indicative of the existence of a feedback mechanism between the two variables in Pakistan. Bayar, et al (2020) evaluated the impact of institutions and human capital on CO2 emissions in transition countries in the European Union from 2008 to 2018. The study employed cointegration techniques in the analysis. The outcome revealed that human capital has a decreasing effect on CO2 emissions in Croatia, Slovenia, Czenchia and Hungary; while it had a positive impact on emission levels in Latvia and Lithuania, respectively. In a similar study, Aqib and Zalman (2023) examined the influence of human development on environmental sustainability in Pakistan from 1975 to 2020. The authors employed the robust least square regression method, granger causality test and accounting matrix methods for the estimation of the model parameters. The findings of the study affirmed that investing more in advance human development that enhances research in eco-friendly innovations and development would lead to lower CO2 emissions. The findings of the innovation accounting matrix revealed that life expectancy and net enrolment rates as predictors of human capital were essential determinants of CO2 emissions in Pakistan. Adikari, et al (2023) in their research on the relationship between human capital and carbo emissions found that in the long run, a 1% increase in human capital decreases carbon emissions by 1.628%. AfzalHassan and Chen (2021) employed decomposition and decoupling estimation techniques to examine the relationship between human development and CO2 emissions in Bangladesh. The scope of the study was from 1990 to 2018. The findings of the study from the index decomposition revealed that variations in economic factor activity produces about 105% CO2 emissions in the country. The study further found that energy intensity and economic structure factors intensified the rise in CO2 emissions by about 10.77% and 2.77%, respectively. Li and Li (2022) also utilised the same method to investigate the relationship between human development index (HDI) and CO2 emissions. The panel data study comprised of 189 countries and spanned from 1990 to 2019. The findings of the study indicated that countries that achieved strong decoupling have high human development. Moreover, the result showed that the carbon emission performance (CEP) for most countries in the survey showed an upward trend; and countries with high human development and low CEP were mainly within the regions of Europe, North America and Central Asia.

On the second strand, Ifelunini, et al (2022) examined the nexus between economic growth, governance and CO2 emissions in countries of the sub-Saharan West African region. The study spanned from 2000 to 2020. The panel study employed the instrumental variable fixed effects estimator and the instrumental variable quantile regression methods. The findings revealed that economic growth significantly impacted on CO2 emissions in the region. In addition, the outcome showed evidence of the existence of the Kuznets curve in the region. Moreover, the results further indicated that the influence of economic growth on CO2 emission is higher in countries with high prior volume of CO2 emissions. In a similar vein, Aye and Edoja (2017) empirically examined the effect of economic growth on CO2 emission in 31 developing countries in Africa. The result of the study indicated that economic growth has a negative effect on CO2 emissions in regimes with low growth levels, but the findings were different in regimes with high economic growth as higher marginal effects were found. The study concluded with no empirical support for the Kuznets hypothesis among the 31 countries. Osadume and University (2021) examined the impact of economic growth on carbon emissions in selected countries in sub-Saharan West Africa. The study spanned from 1980 to 2019. The study observed that economic growth positively and significantly impacted on the level of CO2 emissions in the focus countries. Alaganthiran and Anaba (2022) employed a panel approach in the study of the effects of economic growth on carbon dioxide emissions in selected countries in the sub-Saharan African. Secondary data from 20 countries were collected from 2000 to 2020. The outcome from the robust fixed effects model revealed evidence of a significant relationship between economic growth, energy consumption, tourism sector population and CO2 emissions in the sample. Moreover, the findings showed that a 1% increase in economic growth exerted a positive impact of 0.02% on CO2 emissions in the region. Similar outcome was equally reached by Li, et al (2021) in their study of per capita emissions and the effects of economic growth, social and trade changes in 147 countries from 1990 to 2015. The study noted that a 1% increase in economic activities exacerbated air carbon dioxide emissions by 0.93%. Musibau, et al (2020) in their study of the nexus between environmental degradation, energy use and economic growth, noted that the impact of the rise in economic activities on CO2 emissions was positive and significant only found in the short run, while in the long run, economic growth has a negative effect on CO2 emissions. Lin, et al (2015) examined the impact of industrialization on CO2 emissions in Nigeria. The study spanned from 1980 to 2011 and utilised the vector error correction model (VECM) estimation method. The findings showed that industrial value-added has a significant and inverse relationship with CO2 emissions in the country. However, GDP per capita and population exerted positive influence on CO2 in the county.

The impact of energy depletion and environmental pollution has also been previously researched by scholars. For instance, Abbasi, et al (2021) investigated the impact of energy depletion and renewable energy on CO2 emissions in Thailand. The study utilised the dynamic ARDL approach. The findings showed that the pace of energy depletion has a significant impact on CO2 emissions in both the short and long run time periods. Additionally, the study observed that the depletion rate of non-renewable energy and GDP revealed a positive and statistically substantial effects on CO2 emissions in the short and long run. Lin and Ullah (2024) investigated the effectiveness of energy depletion, green growth and technological cooperation grants on CO2 emissions in Pakistan. The findings revealed that energy depletion in the long run has a contamination effect and hence devalues the quality of the environment. Ali, et al (2021) comparatively evaluated the nexus between natural resources depletion, renewable energy consumption and environmental degradation across several developing and developed countries. The study found an insignificant relationship between natural resource depletion and environmental degradation in the complete sample. Moreover, the findings revealed that energy consumption also has a positive and significant impact on environmental degradation in developing countries. Mirza, et al (2020) examined the impact of energy efficiency on CO2 emissions in 30 developing countries. The study spanned from 1990 to 2016. The findings showed that energy efficiency improvements significantly mitigated CO2 emissions, and thus relate the point that energy efficiency is a significant mitigator of CO2 emissions.

3. Methodology

The broad objective of the study is to estimate the impact of human development, real output and energy depletion on CO2 emissions in Nigeria. Consequently, the research employed annual time series sequences from 1996 to 2022. Accordingly, historical sequences on human development proxied by the human capital index (HDI), real output (RGDP), energy depletion (ENE_D) and CO2 emissions (proxy for environmental pollution) were obtained from the World Bank Development Indicators, 2023. Following Koginam and Ekiye (2019), the study adopts the Cobb-Douglas framework in the estimation of the impact of human development, real output and energy depletion in environmental degradation in Nigeria. The functional form of the environmental pollution model is specified as:

$$CO2 = f\,(HDI, RGDP, ENE\_D) \quad (1)$$

Where:

CO2 = carbon dioxide emission (proxy for environmental pollution)
RGDP = real gross domestic product (proxy for real output)
HDI = Human development index (proxy for human development)
ENE_D = Energy depletion

The econometric specification of the environmental pollution model in equation 1 is stated as:

$$CO2_t = \beta_0 + \beta_1 HDI_t + \beta_2 RGDP_t + \beta_3 ENE_t + \beta_4 D_t + \mu_t \quad (2)$$

The theoretical expectations for the coefficients of equation 2 are Moreover, to decide on the appropriate econometric procedure for the estimation of the environmental pollution function, the Augmented Dickey Fuller (ADF) unit root test was used to determine the order of integration of the variables. The result shows a mixed order of integration (See: Table 3). Accordingly, since the Autoregressive Distributed Lag approach (ARDL) permits estimation of variables with mixed order of integration, it was employed in the econometric analysis of the resource depletion model.

Pesaran and Shin (1999) developed the ARDL for the cointegration analysis of models with variables having mixed unit root properties. Improvements in the ARDL method ensures the estimation of the dependent and explanatory variables with different lags as well as the use of fixed regressors, which is impossible in other conventional methods used for the test of cointegration. Moreover, the ARDL gives robust estimates even for small data sets, and is therefore suitable for the present study that spans from 1990 to 2022, a period of 32 years.

The general specification of the ARDL(p,q) is as follows:

$$\Delta y_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta y_{t-1} + \sum_{j=1}^{q} y_j x_{t-j} + \varepsilon t \quad (3)$$

where y_t is the dependent variable, X_t is a vector of the dynamic explanatory variables which and ε_t is the error term that should be normally distributed with zero mean and constant variance $\varepsilon_t \sim N(0, \sigma^2)$, p and q are the number of lags for dependent and explanatory variables; respectively.

To test for whether there is long-run relationship (cointegration) between y_t and X_t, the bound test equation is specified as follows:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\Delta y_{t-1} + \sum_{j=1}^{q} \varphi_{1i}\Delta x_{t-1} + W_o Y_{t-1} + W_1 X_{t-1} + \mu_t \quad (4)$$

where β_1, and are the parameters of the short-run relationship; and are the parameters of long-run relationship. Accordingly, cointegration between y_t and X_t exists if the null hypothesis, H_0: = 0 is rejected against the alternative H_1: $\neq \neq 0$.

In addition, the existence of cointegration relationship in the models, also necessitates an evaluation of the error correction model (ECM). The equation of the ECM is specified as follows:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_{it}\,\Delta Y_{t-1} + \sum_{j=1}^{q} \varphi_{1i}\,\Delta X_{t-j} + \phi_0 ECM_{t-1} + u_t \quad (5)$$

In actual fact, the term of the ECM_{t-1} is derived from the lagged value of the error term (μ_{t-1}) of the following long-run relationships:

$$y_t = a_0 + \sum_{j-1}^{q} y_j x_t + \mu_t \quad (6)$$

$$ECM_{t-1} = \mu_{t-1} = y_{t-1} - \sum_{j-1}^{q} y_j x_t + \quad (7)$$

and < 0 is the parameter of the error correction model ECM_{t-1} that measures the speed of adjustment from any shocks in the short-run back towards the long-run.

4. Results and Discussion

4.1 Descriptive Statistics

To summarize the basic properties of the variables used in the model specification, Table 1 shows their descriptive statistics. The table shows that the variables have positive mean and median values, respectively. Economic growth (RGDP) has the highest maximum value at 378925.6, whereas, environmental pollution (CO2) has the lowest minimum value at 0.408000. In addition, the standard deviation of each variable in the model highlights the level of dispersion, and shows that CO2 has the lowest standard deviation close to the mean, while RGDP has the highest standard deviation from the mean. Moreover, the probability values of the Jarque Bera statistic at 5% level of significance suggest the non-rejection of the null hypothesis for all the variables and therefore signals the normality of the residual.

Table 1: Descriptive Statistics

	CO2	HDI	RGDP	ENE_DEP
Mean	0.648250	8.262719	283362.9	7.291995
Median	0.653500	8.471000	280480.3	7.018372
Maximum	0.882000	10.51400	379251.6	19.26850
Minimum	0.408000	5.835000	202255.7	1.268139
Std. Dev.	0.122220	1.281251	65696.90	4.139592
Skewness	-0.248626	-0.208492	0.066417	0.743260
Kurtosis	2.370729	2.229688	1.354537	3.545383
Jarque-Bera	0.857654	1.023009	3.633593	3.342914
Probability	0.651272	0.599593	0.162546	0.187973
Sum	20.74400	264.4070	9067612.	233.3438
Sum Sq. Dev.	0.463072	50.88969	1.34E+11	531.2229
Observations	32	32	32	32

4.1 Correlation and Covariance Matrix

Correlation and covariance matrix is preliminary used to assess the degree and direction of relationship between the variables used in the specified model. The result of the correlation matrix is highlighted in Table 2. The correlation matrix as shown in Table 2 suggest that there is a negative association among each of CO2, RGDP, ENE_D. However, a positive correlation is found to exist between CO2 and HDI, as well as between HDI and RGDP. Moreover, the correlation between HDI and RGDP is very significant.

Table 2: Correlation and Covariance matrix

Covariance Correlation	CO2	HDI	RGDP	ENE_D
CO2	0.014471			
	1.000000			
HDI	0.006689	1.590303		
	0.044094	1.000000		
RGDP	-1985.281	65207.87	4.18E+09	
	-0.255224	0.799667	1.000000	
ENE_D	-0.019666	-4.015281	-181180.2	16.60072
	-0.040124	-0.781471	-0.687696	1.000000

Source: Author’s Computation, 2024.

4.3 Unit Root Test

The result of the Augmented Dickey Fuller (ADF) test at levels and first difference is shown in Table 3 below. The ADF Test was conducted at the intercept levels. The outcome shows that the variables were all integrated at first difference, except for energy depletion that was integrated at levels.

Table 3: ADF Unit Root Test

TEST	*CO2*	*HDI*	*GDP*	*ENE_D*
	-2.957110	-2.960411	-2.960411	-3.568379
	(0.0672)	(0.7300)	(0.7675)	(0.0025)
	-2.960411	-2.960411	-2.960411	-3.612199
	(0.0000)	(0.0098)	(0.0575)	(0.6508)

Source: Author's Computation, 2024.

4.4 Analysis of Cointegration

The outcome of the ADF unit root test suggest the applicability of the ARDL bound test approach. However, before the application of the cointegration technique, it is imperative that the optimal lag length is verified. According, the result of the optimal model selection as chosen by the Akaike Information Criteria (AIC) is shown in Figure 1. The table shows that the ARDL model 4,4,4,4 is preferred and the reason is because it has the lowest value among the values of the AIC

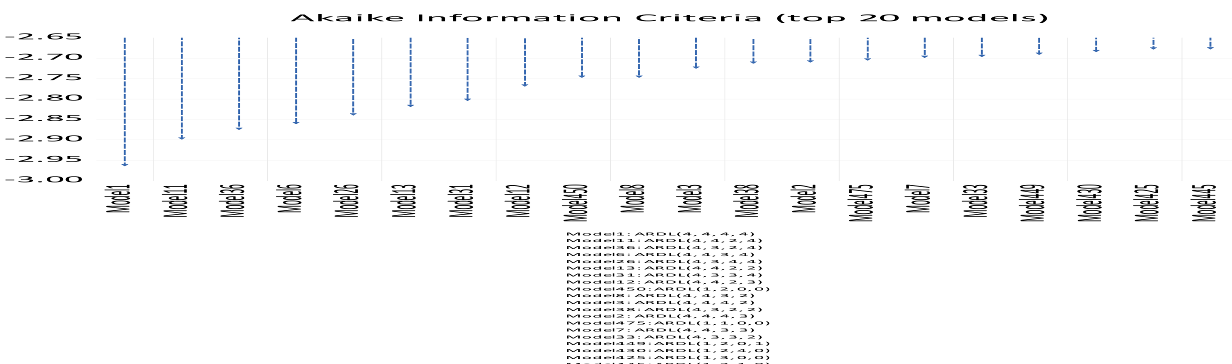

Figure 1 Model Order Selection

4.5 ARDL Bound Test

Upon ascertaining the preferred ARDL model, the study went further to investigate whether there is long run relationship between variables in the model using the ARDL bound test approach. The result of the bound test is found in Table 4.

Table 4. ARDL Bound Test Output

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	14.30538	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Source: Author's Computation, 2024.

The null hypothesis of the bound test proposes that there is no levels relationship existing between the variables in the model. The acceptance or rejection of the null hypothesis is based on the value of the F. statistic vis a vis the lower and upper bound values at the different levels of significance. The result shows that the F. statistic value (14.30538) is higher than the lower and upper bound values at all the significant levels, which therefore suggest that there is a long run cointegration relationship between environmental pollution (CO2) and the dynamic regressors in the specified model.

Long-run Estimates (ARDL Model - 4.4.4.4)

The signs and magnitudes of the coefficients of variables in the environmental degradation model in the long run are shown in Table 5. The outcome suggests that the human development index and energy depletion have statistically significant impact on environmental pollution in Nigeria. The sign of ENE_D is negative and conforms to economic theory. The result suggests in the long run, as energy depletion rises by 1%, it could lead to a dip in environmental pollution by as much as 2.67%. The findings further highlights an inverse relationship between the human development (HDI) and environmental pollution, and shows that as HDI increases by 1, the estimated decrease in environmental pollution is 10.2% in the long run. The result also indicates that the direction of the estimated relationship between real output and environmental pollution is negative and statistically not significant at the 5% level of significance.

Table 5:Long-run Output of the ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
HDI	-0.102068	0.031285	-3.262530	0.0115
RGDP	-2.81E-07	3.77E-07	-0.745431	0.4773
ENE_DEP	-0.026717	0.009597	-2.783752	0.0238
C	1.763367	0.273029	6.458545	0.0002

Source: Author's Computation, 2024.

The ECM and short run estimates of the ARDL model are shown in Table 6. The findings show that the parameters are statistically significant at various lags. The ECM is correctly signed and its value (-1.420365) indicates that about 14% of short run shock will be corrected annually. Interestingly, the table shows the mixed effects of human development (HDI) and productive activities (RGDP) on environmental degradation in the short run. The highlights show the mixed impact of HDI on environmental degradation in the short run. Precisely, the findings suggest that a 1% increase in the human development index reduces environmental degradation by 15%; but this is counteracted in the first, second and third lags, respectively. The outcome also revealed that increase in economic activities is a positive predictor of environmental pollution in Nigeria, even though the coefficient is not statistically significant. Again, the influence of energy depletion (ENE_D) on environmental pollution in Nigeria is observed to be statistically significant, thus suggesting that an increase in the expropriation and use of energy resources significantly drives environmental pollution in the short run. Moreover, the explanatory power of the model is high and the Durbin Watson Statistic value attest to the absence of serial correlation in the estimated model.

Table 6: Short-Run Output (ARDL Model 4.4.4.4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(HDI)	-0.149911	0.060833	-2.464322	0.0391
D(HDI(-1))	0.221767	0.065682	3.376388	0.0097
D(HDI(-2))	0.126751	0.065852	1.924779	0.0904
D(HDI(-3))	0.125971	0.053409	2.358609	0.0461
D(RGDP)	0.000002.23	0.00000120	1.856296	0.1005
D(RGDP(-1))	0.0000044	0.00000151	1.620127	0.1439
D(RGDP(-2))	0.000002.69	0.00000167	1.610464	0.1460
D(RGDP(-3))	-0.00000261	0.000001.33	-1.965741	0.0849
D(ENE_D(-1))	0.027004	0.003838	7.035063	0.0001
D(ENE_D(-2))	0.011729	0.003865	3.034643	0.0162
D(ENE_D(-3))	0.009467	0.003401	2.783314	0.0238
ECM(-1)*	-1.420365	0.137126	-10.35810	0.0000

R-squared	0.920765	Mean dependent var	0.006357
Adjusted R-squared	0.821721	S.D. dependent var	0.097487
S.E. of regression	0.041162	Akaike info criterion	-3.247040
Sum squared resid	0.020332	Schwarz criterion	-2.485780
Log likelihood	61.45856	Hannan-Quinn criter.	-3.014315
Durbin-Watson stat	2.300810		

Source: Aurthor's Computation, 2024.

4.6 Post-Diagnostic Tests

Furthermore, post-estimation tests of the output of the specified model were conducted. The result is shown in Table 7 below. The table highlights the result of the Breusch Godfrey (BG) Serial correlation LM test, Breusch-Pagan-Godfrey heteroscedasticity test and the Jarque Bera test for normality. The output suggests that the BG and BPG tests with the null hypothesis of no serial correlation in the residuals and no heteroscedacity cannot be rejected as their p-values are greater than the adopted 5% level of significance in both the F test and Obs.*R-Square statistic. Moreover, Figure 2 shows that the Jarque Bera test of Normality is in conformity with expectations as the J.B probability value of 0.35 is above the 5% significance level.

Table 7. Post Estimation Diagnostic Tests Output

Breusch-Godfrey (LM) Test for Serial Correlation			
F-statistic	3.019212	Prob. F(2,6)	0.1238
F-statistic	0.282790	Prob. F(19,8)	0.9887
Obs*R-squared	11.24986	Prob. Chi-Square(19)	0.9151

Source: Author's Computation, 2024.

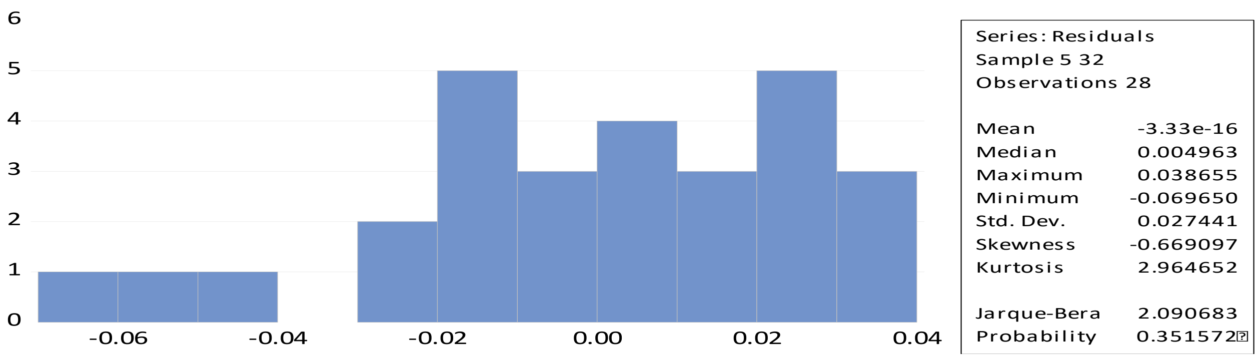

Figure 2. Normality Chart

4.7 Discussion of Findings

This section begins by discussing the response of the explanatory variables on environmental pollution in Nigeria. The result of the ARDL bound test estimation shows that all the independent variables together influence the environment in the long run. The long run estimates of the environmental pollution model show that human development, economic growth and energy depletion have a depressing impact on carbon emissions. On the first objective, the result of the ARDL bound test shows the existence of a long run relationship between human development, economic growth, energy depletion and carbon emission in Nigeria. The result of the bound test affirms that these variables are determinants of CO2 emission during the period under study. This outcome is not out of place as human activities in production and consumption could exert considerable influence on the volume of carbon emission at a point in time.

Continuing, on the second objective of the study which is to determine the specific impact of human development, economic growth and energy depletion on CO2 emission during the period under study, the result shows that the human development index responded positively to environmental pollution in the short run time period. Although, the coefficient of the first lag was negative, the succeeding lags were positive and statistically significant. However, the positive influence is countered in the long-run, thus revealing the impact that investment in human capital development could have on the environment as human development could engender the adoption of innovative and sustainable mechanisms that improves environmental quality and mitigate emission levels in the long-run. The study of Yao, et al (2020) also noted that advancing human capital development could lead to reduced carbon dioxide emissions in the long run.

The study findings further showed that real output exerts positive influence on the quantity of CO2 emission in the short run. This outcome is indicative of the impact that rising production activities could have on the environment, especially when nothing is done. The environment is often degraded through negative spillovers continually deposited on it from extractive, manufacturing and transportation activities. Even though these activities enhance the economy and generate employment, they not only stress but devalue the environmental system. However, the findings showed that in the long run, the influence of real output on the environment is negative. Precisely, the findings reveal that environmental pollution decreased by 0.000000281% for every 1% increase in economic growth in the long run. The outcome therefore suggests that rising economic activities at first exacerbates the environmental problem, and this could be attributed to the scale effect of increasing productivity and lack of awareness of people on the imperative of a sustainable environment for improvement in the livelihood of the populace. However, in latter periods, change in technology, knowledge and the composition of economic activities - in such ways that leads to the decline in the use and spill of environmental unfriendly fossil fuels from the industrial sector could improve environment quality.

Furthermore, the findings show that energy depletion (ENE_D) responded positively to environmental pollution in all the lags in the short-run period. The paper argues that this implies that energy depletion devalues the quality of the environment. Extraction and use of non-renewable energy resources (coal, crude oil and natural gas) using high precision technologies distorts the structure of the natural environment. Besides, negative spillovers from smoke, effluents and toxic chemicals on the environment during exploration and exploitation processes could also distort environmental quality and affect the natural processes of species. The second lag of ENE_D indicate that a 1% increase in energy depletion increases environmental degradation by 0.012% in the short run. This outcome could be related to human production and consumption activities that requires the use of fossil fuels. The paper argues that energy intensity accentuated by the burning of fossil fuels releases carbon dioxide into the atmosphere. However, the findings as shown by the negative coefficient of ENE_D further indicate that this impact on the environment could be mitigated in the long run. The long-run coefficient of ENE_D reveals that environmental degradation decreases by 0.027 for every 1% increase in energy depletion. The rationale for this may not be unconnected to the strategic goal in the area of air pollution undertaken globally that now requires countries to de-emphasis the use of non-renewable energy sources that pollute the environment in industrial and transportation activities. It is argued that with such goals, the depletion of non-renewable energy resources is expected to decrease in the long run due to lower energy consumption made possible by innovative technological changes in industrial energy sources and fuel switching mechanical systems in transportation. Therefore, this could engender an inverse relationship between environmental pollution (CO2 emission) and energy depletion in the long run.

5. Conclusion and Recommendations

In an effort to ensure economic prosperity, developing countries engage in production and investment activities to help create jobs, generate incomes for people and grow their economies. For many countries, these activities are bolstered through the dynamic combination of human capital and natural resources. In fact, it is well documented that the level of human development has positive relationship with production activities in a country (Becker, 1994; Romer, 1990). Although, the macroeconomic goal of sustained growth in national output is not out of place, the problem with such an objective has been the prospect of increased carbon emissions and environmental pollution.

The seriousness of the problem of environmental degradation is observed in the many global strategic agreements among developed and developing countries. These agreements and the goals set therein have contributed to more elaborate research on the nexus between human development, economic growth and environmental degradation. Consequently, it is expected that in tandem with the global goal of sustainable environment, that across the world, carbon dioxide emission is expected to decline in the long run. This, in part would be due to decreased consumption of fossil fuels, and the rise in the use of fuel switching mechanical processes and devices. Consequently, these findings while they in part, point to the influence of human development, real output and energy depletion as drivers of environmental degradation in Nigeria; the findings also suggest the need for the country to reduce the pollution of the environment by formulating sustainable policies.

A critical challenge for Nigeria is sustaining the growth of national output, while evolving new energy mechanisms that would ensure seamless switch from its high intensity fossil-fuel dependent economy to renewable energy resources. The challenge is intensified by the fact that the cost of such a transition on a national scale may be quite high in countries where many individuals have low incomes and do not have the requisite education, and skills to adopt cleaner energy production systems; and the environmental laws and regulatory institution is non-stringent and weak. However, the reverse would be the case where there is advanced development of the human capital resources in the country.

To this end, the paper suggests that the social benefits of human development to the economy and the environment is high, therefore, national and subnational government in Nigeria should actively invest financial resources in advancing the human capital base of people in their localities. This is because of the high propensity for a well-educated population to better understand and adopt measures that require the use of cleaner energy sources in production and consumption activities and so, reduce the devaluation that is caused by the rise in economic activities on the natural environment. In addition, there is the need for more stringent environmental laws that penalizes environmental pollution. This would act to deter economic agents whose production systems engender environmental pollution and also help in the fight against climate change.

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