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Environmental Impact of Natural Gas Utilization in Nigeria

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ABSTRACT: This study evaluates the environmental impact of natural gas utilization in Nigeria from 2000 to 2022, employing the Autoregressive Distributed Lag (ARDL) model. The analysis investigates the relationship between total carbon dioxide emissions (TCO_2E), domestic natural gas supply (NG_SD), and economic growth proxied by Gross Domestic Product (GDP). The results revealed significant short-run effects of both NG_SD and GDP on TCO_2E. Specifically, a 1-unit increase in NG_SD raises TCO_2E by 0.148 units, while a 1-unit increase in GDP results in a 0.0773 unit rise in emissions. Lagged effects show that past increases in NG_SD and GDP reduce emissions, suggesting the substitution of cleaner energy sources and technological advancements. However, the bounds test indicates no co-integration between TCO_2E, NG_SD, and GDP, implying the absence of a stable long-term relationship. Diagnostic tests validate the model's reliability, with no evidence of autocorrelation, heteroskedasticity, or instability. The R-squared (86.65%) demonstrates a strong explanatory power, while the Cumulative Sum (CUSUM) and Cumulative Sum of Square (CUSUMSQ) tests confirmed the parameter stability. The findings highlight that Nigeria's reliance on natural gas and economic growth strategies increases emissions in the short run but lacks sustained long-term impact. This underscores the need for short-term policy interventions, such as promoting renewable energy, carbon pricing, and green technologies. Transitioning from natural gas to cleaner energy sources is essential to achieve emissions reduction. Regular policy reviews are recommended to adapt to evolving dynamics in emissions and energy consumption.

KEYWORDS: Natural gas, carbon emissions, GDP, energy policy, emissions reduction, renewable energy, greenhouse gas.

I. INTRODUCTION

Natural gas has emerged as a vital energy resource in the global quest for sustainable development, providing a cleaner alternative to coal and oil. For Nigeria, a nation endowed with significant natural gas reserves, the utilization of this resource is critical for achieving energy security and driving economic growth. Nigeria's estimated natural gas reserves, exceeding 200 trillion cubic feet, position the country as one of the largest natural gas producers in Africa and the world [1,2]. However, while natural gas utilization offers substantial economic benefits, its environmental impact raises critical concerns that demand thorough examination [3].

The environmental implications of natural gas utilization are multifaceted, ranging from greenhouse gas (GHG) emissions to land degradation and water contamination. Unlike other fossil fuels, natural gas is often promoted as a "bridge fuel" due to its lower carbon dioxide (CO_2) emissions per unit of energy produced [4, 5, 6]. Nevertheless, methane (CH4), a potent GHG, is frequently released during natural gas production, processing, and transportation. In Nigeria, the flaring of associated gas has been a persistent issue, contributing significantly to the country's GHG emissions and undermining its commitments to international climate agreements such as the Paris Accord [7].

Economic growth in Nigeria has often been closely linked to the exploitation of its natural resources, particularly oil and gas. The nation's dependency on hydrocarbon revenues for foreign exchange and fiscal stability has incentivized policies promoting natural gas development [8]. However, the environmental trade-offs of these policies are increasingly becoming apparent. For instance, as natural gas becomes a central pillar in Nigeria's energy transition strategy, its potential to exacerbate environmental degradation—through gas flaring, deforestation for pipeline installations, and the release of pollutants—necessitates an evidence-based approach to policy formulation [9, 10].

The environmental impact of natural gas utilization in Nigeria also extends to public health and socio-economic conditions. Communities located near gas production facilities often face exposure to air pollutants, including nitrogen oxides (NOx) and volatile organic compounds (VOCs), which can lead to respiratory illnesses and other health complications [11,12,13]. Additionally, the environmental degradation associated with gas projects frequently disrupts agricultural activities, fisheries, and livelihoods in rural areas, compounding the socio-economic inequalities in the country [14].

Despite the growing body of literature on the environmental and socio-economic impacts of fossil fuel utilization, research focusing specifically on the dynamics of natural gas impact on the environment, particularly CO_2 emission in Nigeria remains limited. Much of the existing discourse has concentrated on oil production, with natural gas often treated as a secondary issue [15]. This oversight is particularly concerning given the Nigerian government's recent push to position natural gas as the cornerstone of its energy transition strategy, as outlined in the "Decade of Gas" initiative [3].

This study aims to fill this research gap by evaluating the environmental impact of natural gas utilization in Nigeria from 2000 to 2022. The research employs the Autoregressive Distributed Lag (ARDL) model to investigates the short- and long-term relationships between natural gas utilization proxied by natural gas supply (NG_SD), GDP, and environmental impact proxied by carbon emissions(TCO_2E). By focusing on these interdependencies, the study provides critical insights into whether Nigeria's reliance on natural gas aligns with global sustainable development goals.

The theoretical foundation for this research is grounded in the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation initially worsens with economic growth but improves once a certain income threshold is reached [16]. The EKC framework is particularly relevant for Nigeria, a developing country striving to balance economic growth with environmental sustainability. Understanding whether natural gas utilization contributes to or mitigates environmental degradation within this framework will inform both academic debates and policy interventions.

II. MATERIAL AND METHODS

Materials

This paper presents the results of empirical research using secondary time series annual data mined from online sources. Related data on Nigeria's natural gas production, supply and export were sourced from the International Energy Agency (IEA). The gross domestic product (GDP) data was sourced from the online from World Bankat the Macrotrend website, data on CO_2 emissions were sourced from the websites of the International Energy Agency (IEA), World Bank, and Statista. The data were processed to align related variable units and fitness for EViews software upload and analysis.

Analytical Model

The processed time series data were analyzed using the Autoregressive Distributed Lag (ARDL) Model. The ARDL model is useful in handling variables of single or mixed order of integration, requires that certain assumptions must be satisfied to use it to estimate the long and short-run model. These assumptions include model diagnostic and parameter fitness, residual, and stability diagnostics. The ARDL approach involves performing a bound test to determine if co-integration exists between the dependent and independent variables. Where co-integration is established, long-run coefficients are determined using the ARDL model specifications of equation 1.

$$\mathbf{E_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i E_{t-i} + \sum_{j=0}^{q} \beta_j G_{t-j} + \sum_{k=0}^{r} \gamma_k X_{t-k} + \epsilon_t} (1)$$

Where:

- E_t (Environmental Effect) is the dependent variable.
- G_t (Natural Gas Utilization) is the independent variable
- X_t Represents control variables (GDP).
- $E_{t-i}, G_{t-j} \& X_{t-k}$ represents the variables lagged by $(i, j \& k)$Periods.
- (α_i), (β_j) and (γ_k) are the coefficients of the lagged dependent and independent variables, respectively.
- (ϵ_t) is the error term.

The Error Correction Model (ECM) is estimated to capture the short-run dynamics and speed of adjustment towards long-run equilibrium. This is given by equation 2;

$$\Delta P_t = \lambda_0 + \sum_{i=1}^{p-1} \lambda_i \Delta P_{t-i} + \sum_{j=0}^{q-1} \delta_j \Delta G_{t-j} + \sum_{k=0}^{r-1} \theta_k \Delta X_{t-k} + \phi ECT_{t-1} + \epsilon_t \qquad (2)$$

Where ECT_{t-1} is the error correction term derived from the long-run relationship.

The research variables comprise the Environmental Effect (E_t) proxied by Total CO_2 Emission (TCO_2E) in Metric Tons of Carbon Dioxide (Mt CO_2), as the dependent variable, Domestic Natural Gas Utilization (G_t) proxied by Natural Gas Supply (NG_SD) in Trillion standard cubic feet (Tscf) as independent variableand Economic Growth (X_t)proxied by Gross Domestic Product (GDP) in US$ Billion as a control variable.

Methodology

The study employed the Autoregressive Distributed Lag (ARDL) model to explore the short-run and long-run effects of the environmental impact of natural gas utilization in Nigeria, utilizing time series data from 2000 to 2022. The model methodology involves the definition of research objectives, processing and refining research data, perform descriptive statistics to provide an overview of the central tendency, dispersion, and distribution of the variables such as the mean, median, skewness, kurtosis, and normality of the variables. Next, the time series plots provide stylized facts on the correlation between key research variables. Furthermore, econometric methods test and evaluate the environmental impact of natural gas usage. The study adopts EViews software for the model analysis.

III. RESULTS

Table 1 indicates that the dataset showed moderate variability, normal distribution, and a reasonable number of observations. The standard deviations for NG_SD (55.18395), GDP (156.9997), and TCO2E (11.51262) showed moderate variability suggesting data stability. The absence of extreme skewness and kurtosis values implies that the data may not exhibit high levels of volatility. However, formal stationarity tests are required to validate the dataset for econometric modeling. The Jarque-Bera test indicates that all variables NG_SD, p-value (0.528968) > 0.05; GDP, p-value (0.377928) > 0.05; and TCO2E p-value (0.576912) > 0.05 are normally distributed, implying that the variable datasets are suitable for ARDL model analysis subject to further robustness checks.

Table 1: Descriptive Statistic Result

Descriptive Statistics	NG_SD	GDP	TCO2E
Mean	166.8296	333.0534	101.0036
Median	178.5100	375.7457	100.9949
Maximum	260.9300	574.1838	119.5441
Minimum	74.00000	69.17145	76.94740
Std. Dev.	55.18395	156.9997	11.51262
Skewness	-0.109850	-0.450042	-0.360686
Kurtosis	1.868292	1.895209	2.207795
Jarque-Bera	1.273654	1.946103	1.100133
Probability	0.528968	0.377928	0.576912
Sum	3837.080	7660.228	2323.082
Sum Sq. Dev.	66995.91	542275.7	2915.891
Observations	23	23	23

NOTE: ***, ** and * indicate significance at 1%, 5% and 10% level of significance.

Time Series Plot

The time series plot of natural gas utilization, TCO_2E and GDP in Nigeria provides critical insights into their trends and relationships over time.

The graphs of Figures 1 and Figure 2 depict the relationship between CO_2 emissions and natural gas supply in Nigeria from 2000 to 2022. It includes variables such as Total CO_2 Emissions (TCO_2E), CO_2 Emissions from Natural Gas (CO_2E_NG), CO_2 Emissions from the Power and Industrial Sector (CO_2E_PI), and Domestic Natural Gas Supply (NG_SD).

The graph showed a stable trend with slight fluctuations over time, suggesting that TCO_2E have not changed drastically despite other variables increasing. CO_2 emissions from natural gas have increased steadily since around 2004, reflecting an increasing reliance on natural gas for energy. However, CO_2 emissions from the Power and Industrial Sectors remain relatively stable, with slight increases over time. A strong positive correlation exists between NG_SD and CO_2E_NG, suggesting that more natural gas is being burned, likely for power generation and industrial use. The rise in NG_SD leads to increased CO_2 emissions from natural gas combustion, showing the direct impact of greater fossil fuel use on emissions. Despite the rise in natural gas-related emissions, TCO_2E remains relatively stable. This indicates that other sectors may be decarbonizing or using less fossil fuels or that natural gas displaces more polluting energy sources like coal or oil. Overall, the graph indicated a clear relationship between the supply of natural gas and the emissions produced from its use. While CO_2 emissions from natural gas have increased with higher natural gas supply, TCO_2E remained relatively stable, suggesting a balancing effect where cleaner natural gas may replace dirtier fuels or other sectors are reducing their emissions.

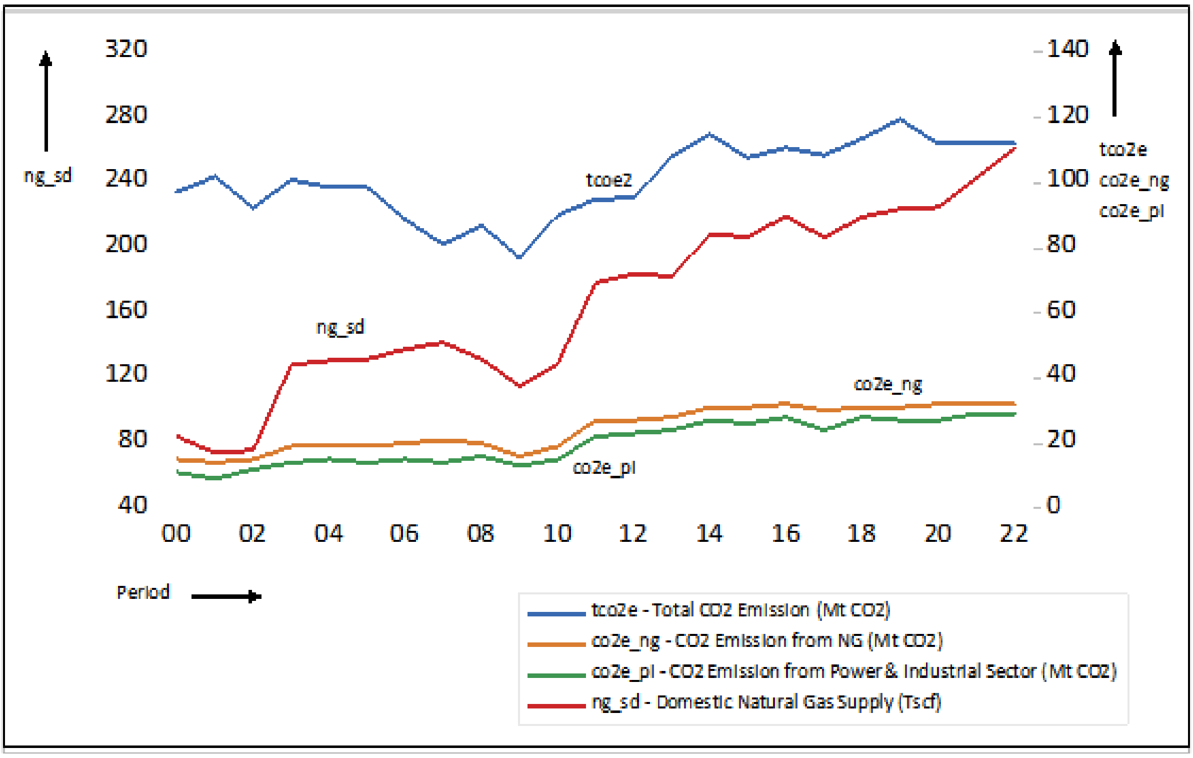

Figure 1: Correlation of Domestic Natural Gas Supply and CO_2 Emissions

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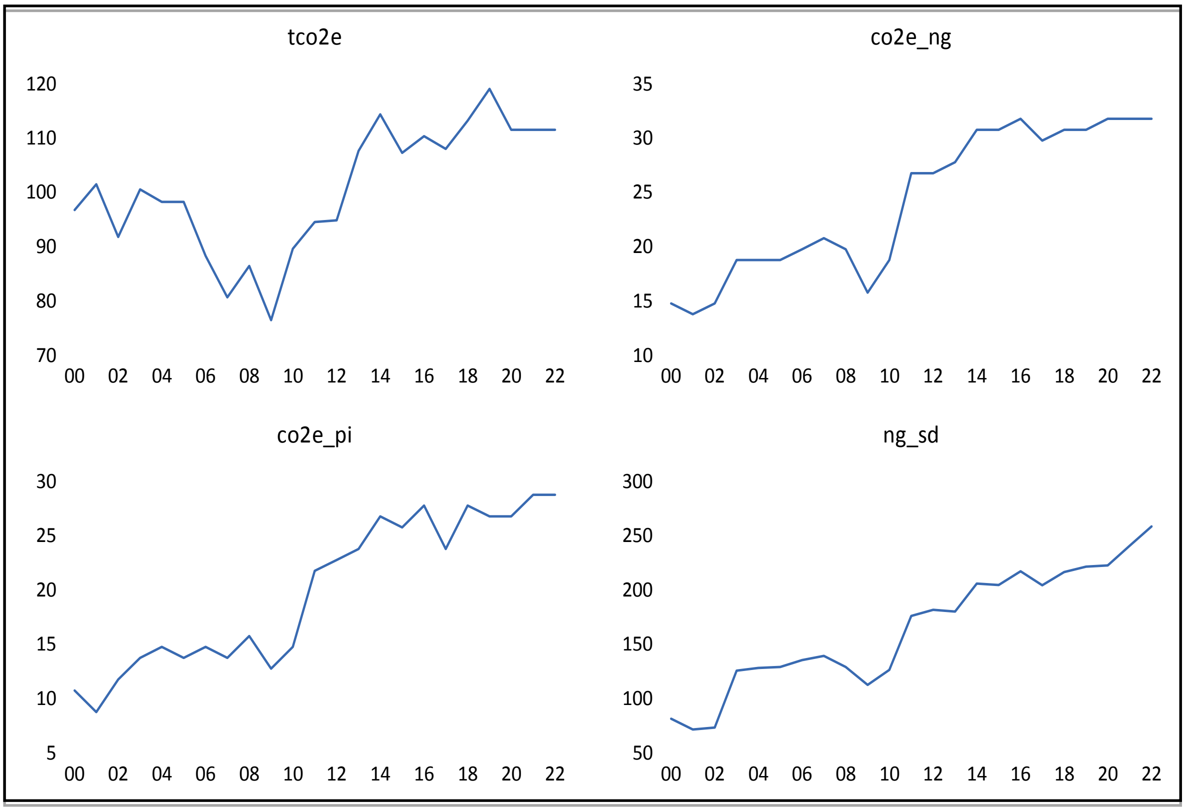

Figure 2: Individual Graph of NG_SD, TCO_2E, CO_2E_NG and CO_2E_PI

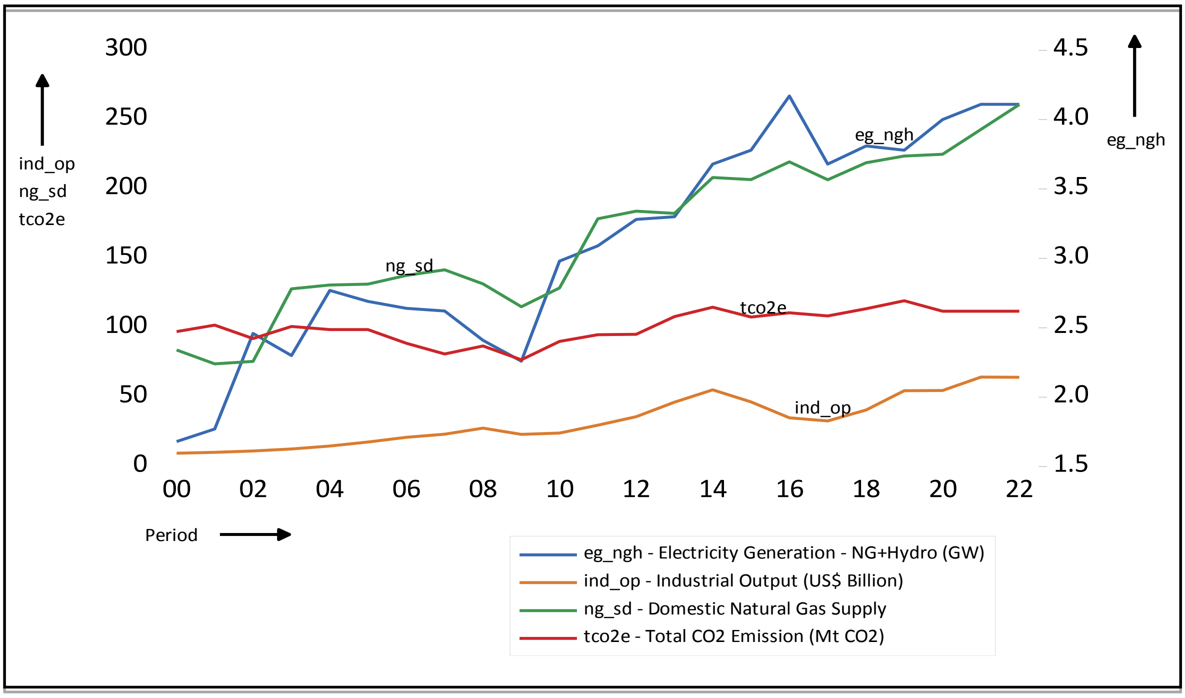

Figure 3: Correlation of Power Generation and Industrial Output on the Environment

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Figure 3 presents data on electricity generation (EG_NGH), industrial output (IND_OP), domestic natural gas supply (NG_SD), and total CO_2 emissions (TCO_2E) in Nigeria from 2000 to 2022. Key observations include a consistent increase in EG_NGH after 2005, indicating a growing reliance on natural gas and hydroelectric sources. IND_OP also showed a steady upward trend, reflecting overall economic growth and increased industrial activity in Nigeria. NG_SD increases over time, with notable growth around the mid-2000s, aligning with the expansion in electricity generation. TCO_2E remains relatively stable, slightly increasing over time. This suggests that rising industrial activity and energy production have not drastically increased emissions, possibly due to a shift towards cleaner energy sources or improved efficiency.

There is a strong positive correlation between electricity generation and natural gas supply, indicating that the greater availability of natural gas largely drives the increase in electricity generation. As industrial output grows, so does the demand for electricity, which is increasingly met by natural gas. TCO_2E exhibits a relatively flat trend despite the growth in electricity generation and industrial output. This suggests that the energy mix has become cleaner, with a more significant proportion of electricity generated from natural gas and others from hydropower. The graph highlighted the dynamic relationship between Nigeria's natural gas supply, electricity generation, industrial output, and CO_2 emissions. While electricity generation and industrial output have increased significantly, the impact on total CO_2 emissions has been moderated, likely due to the growing use of natural gas and hydroelectric power.

Stationarity Consideration& Lag Length Selection.

The stationarity test for the variables was performed using the Augmented Dickey-Fuller (ADF) unit root test. Four tests were conducted for each variable in two stages: At Level @ intercept (C) and intercept & trend (CT) and at 1st Diff @ intercept (C) and intercept & trend (CT). The summarized test results presented in Table 2 indicated that the variables are all of integration order one (I(1)). For the lag length selection, the Unrestricted Vector Autoregressive (UVAR) Lag Length Selection Criteria in EViews was performed to determine the optimal lag lengths, as in Table 2. Generally, the ARDL model is suited to handling variables of integration order zero (I(0)), integration order one (I(1)), or mixed order of I(0) and I(1).

ARDL Model Specification

The ARDL model examines the short-run and long-run relationships. The model is given by the function in equation (3)

$$\mathbf{TCO_2E(t) = f((NG\_SD(t), GDP(t))} \quad \mathbf{(3)}$$

From equation 3, the ARDL Model is given by the equation 4

$$TCO_2E_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i TCO_2E_{t-i} + \sum_{j=0}^{q1} \beta_{1_j} NG\_SD_{t-j} + \sum_{j=0}^{q2} \beta_{2_j} GDP_{t-j} + \epsilon_t \quad (4)$$

The bound test results in Table 3 shows that F-Stat (2.4062) <I(0) (3.1) implies no co-integration, meaning no long-run relationships (only short-run). Equally, R-squared (0.8665) and Adj. R-squared (0.8093) explains 86.65% and 80.93% variability in TCO_2E by the independent variable indicating an excellent fit. The F-Stat. (15.1480) significant at 1% level means the independent variables have a strong impact on TCO_2E.The Durbin-Watson Stat. (2.0250) value is close to 2, suggesting no significant autocorrelation in the residuals.

From Table 4, the coefficient of NG_SD(0.1480) is positive and significant at a 10% level. This suggests that a 1-unit increase in NG_SD in the short run increased TCO_2E by 0.148 units. The coefficient of GDP(0.07734) is positive and significant at the 5% level, indicating that a 1-unit increase in GDP leads to a 0.0773 unit increase in TCO_2E. The model also suggests that the lagged value of NG_SD(-0.1642) has a negative coefficient, significant at a 10% level; this means that past increases in natural gas supply are associated with reductions in CO_2 emissions in the short run. When the natural gas supply increases, it may substitute more carbon-intensive energy sources, reducing CO_2 emissions. Equally, the lagged GDP(-0.1077) has a negative coefficient, which is significant at a 5% level, implying that previous increases in GDP reduce current TCO_2E emissions in the short run. This suggests the previous GDP term may have benefitted from a shift from carbon-intensive energy to cleaner energy sources like natural gas and renewables. The second lag coefficient of GDP (0.0599) is positive and weakly significant at the 10% level, indicating that older GDP growth increases emissions, mostly probably from the use of carbon-intensive energy sources.

The long-run coefficients indicate that neither NG_SD nor GDP significantly affects

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TCO_2E in the long run since the model suggests no co-integration. However, the intercept (55.9025) of the long-run model positive and significant at the 10% level suggests that the TCO_2E level is anchored around 55.9025, holding other factors constant if a long-run relationship exists.

The Error Correction Term (ECT) showed the relationship between the dependent variable and its explanatory variables in the short run. However, the lack of co-integration means the error correction term is irrelevant in this model, as the model does not revert to equilibrium in the long run. However, statistically, from the model, the ECT coefficient $TCO_2E(-1)^*$ = CointEq(-1)* = -0.1918 is negative and statistically significant at 1%. The error correction term is given by the equation below.

EC = TCO2E - (-0.0845*NG_SD + 0.1543*GDP + 55.9025) (5)

Table 2: ADF - Unit Root Test and Lag Length Selection Results

S/N	**Variables**	**t-stat**	**TCV@5% Level**	**Remarks**	**Order of Integration**	**Optimal Lag Length**
1	**NG_SD**	4.6843**	3.0124	NG_SD is only stationary at 1st Diff @ C & C&T only	Order of integration is 1, I(1)	1
2	**GDP**	3.3337**	3.0124	GDP is only stationary at 1st Diff @ C only	Order of integration is 1, I(1)	1
3	**TCO_2E**	5.6432***	3.0124	TCO2E is stationary at 1st Diff @ C and C&T only	Order of integration is 1, I(1)	1

Note:
- C – Intercept
- C & T Intercept & Trend
- TCV – Test Critical Value
- If |t-stat| > |TCV@5%, level|, no unit root, implying variable is stationary
- If |t-stat| < |TCV@5% level|, unit root exists, implying the variable is non-stationary

Table 3: Bound Test and Model Fitness Result

BOUND TEST
Null Hypothesis (H_0): No Co-integration

F-Stat Value	**Signif. Level**	**Lower Bound I(0)**	**Upper Bound I(1)**
2.4062	10%	2.63	3.35
	5%	3.1	3.87
	2.5%	3.55	4.38
	1%	4.13	5
Remarks:	F-Stat (2.4062) <I(1) (3.1), implies no co-integration exist. No long run relationship		
Model Fit & Diagnostic Parameters			
R-Squared	**Adj.R-Squared**	**F-Stats**	**D-W Stat.**
0.8665	0.8093	15.1480***	2.0250

Note:
- D-W Stat: Durbin-Watson Statistics
- F-Stat: F-Statistics

Table 4: ARDL Model Analysis Test Result

Model	Variable	Coefficient	t-Statistic	Prob.*
S. R	TCO2E(-1)	0.808222	0.190067	0.0008
	NG_SD	0.147987	0.078419	0.0801
	NG_SD(-1)	-0.164189	0.078824	0.0561
	GDP	0.077387	0.034145	0.0398
	GDP(-1)	-0.107698	0.044253	0.0289
	GDP(-2)	0.059894	0.028972	0.0577
	C	10.72087	14.13120	0.4606
L. R	NG_SD	-0.084483	0.451941	0.8544
	GDP	0.154258	0.224035	0.5024
	C	55.90251	28.95225	0.0740

Note:

- L.R – Long Run; S.R – Short Run; C – Constant (Intercept);
- (-1) – Coefficient of the lag 1; (-2) – Coefficient of the lag 2; prob* - Probability (p-value)
- EC = TCO_2E - (-0.0845*NG_SD + 0.1543*GDP + 55.9025)
- F-Stat (2.4062) <I(1) (3.1), implies no co-integration exist. No long run relationship
- ***, ** and * indicate significance at 1%, 5% and 10% level of significance.

Residual Diagnostic Results

The result from Table 5 and the histogram normality plot of Figure 4 gives the Jaeque Bera stat. (0.5511) and p-value (0.7591)> 0.05, indicated that the residuals are normally distributed. Equally, from Table 5, the Breusch-Godfrey Serial Correlation LM test result with Obs*R-squared (2.341984) and p-value (0.3101)> 0.05 indicates no serial correlation in the model residuals. Also, the Breusch-Pagan-Godfrey heteroskedasticity test result with Obs*R-squared (5.831282) with p-value ((0.4424)) > 0.05 indicates the model residuals are homoscedastic.

Stability Diagnostics:

The stability tests include the CUSUM of Square Test and the CUSUM Test.

From Figure 5, the CUSUM of Squares line is entirely within the 5% significance bounds throughout the sample period (2009 to 2022). This suggests that there is no evidence of structural breaks or instability in the model parameters during this period. This implies, the model is stable, and there are no significant structural changes or breaks in the relationship between the variables from 2009 to 2022.

From Figure 6, the CUSUM line stays within the 5% significance bounds throughout the period (2009 to 2022). This suggested that the model's coefficients are stable over time, as there are no significant breaks or deviations in the model's structure. The model passes the CUSUM stability test, indicating that the parameters are stable over the sample period. There is no evidence of structural breaks or instability in the model based on this test. Therefore, the model can be considered stable over the period analyzed.

Table 5: Residual Diagnostic Test Results

Residual Diagnostic Test Results			
	Histogram Normality Test Jaeque Bera (Prob)	**Breusch-Godfrey Serial Correlation LM Test:** Obs*R-sqd (Prob)	**HeteroskedasticityTest** Obs*R-sqd (prob)
Results	0.5511 (0.7592)	2.341984 (0.3101)	5.831282 (0.4424)

Note:

- Histogram Normality - Null hypothesis: Residuals are normality distributed
- Serial Correlation LM Test – Null hypothesis: No serial correlation
- Heteroskedasticity Test - Null hypothesis: Homoskedasticity
- Prob = Probability = value in parenthesis = p-value
- If the p-value < 0.05, we reject null hypothesis
- If the p-value > 0.05, we cannot reject null hypothesis

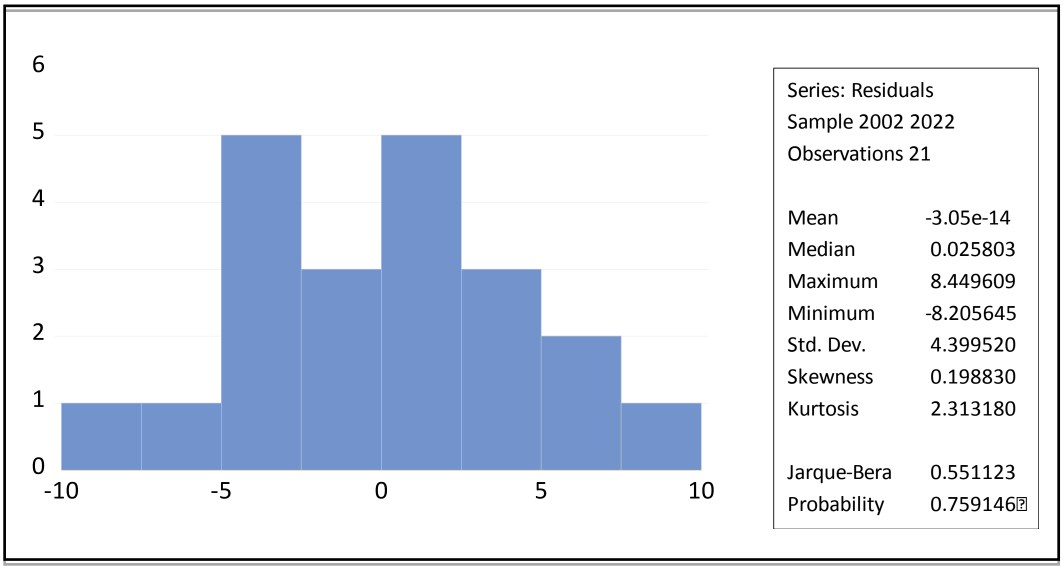

Figure 4: Histogram Normality Plot

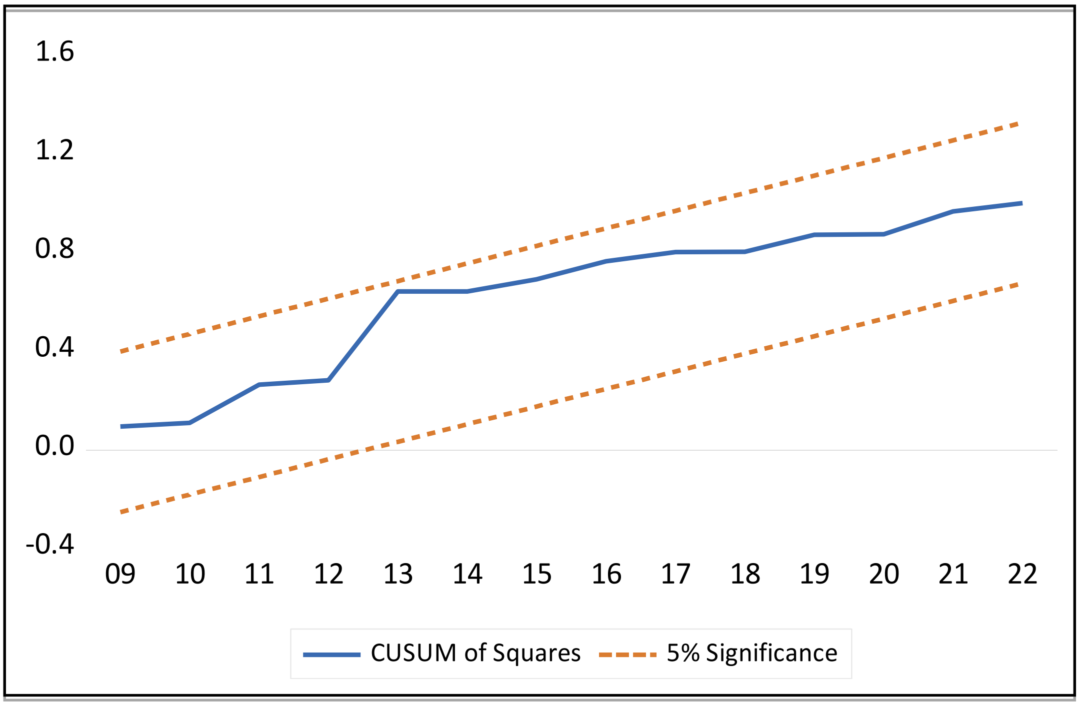

Figure 5: CUSUM of Square Test Plot

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Volume 7, Issue 02 Feb. 2025, pp: 249-260 www.ijaem.net ISSN: 2395-5252

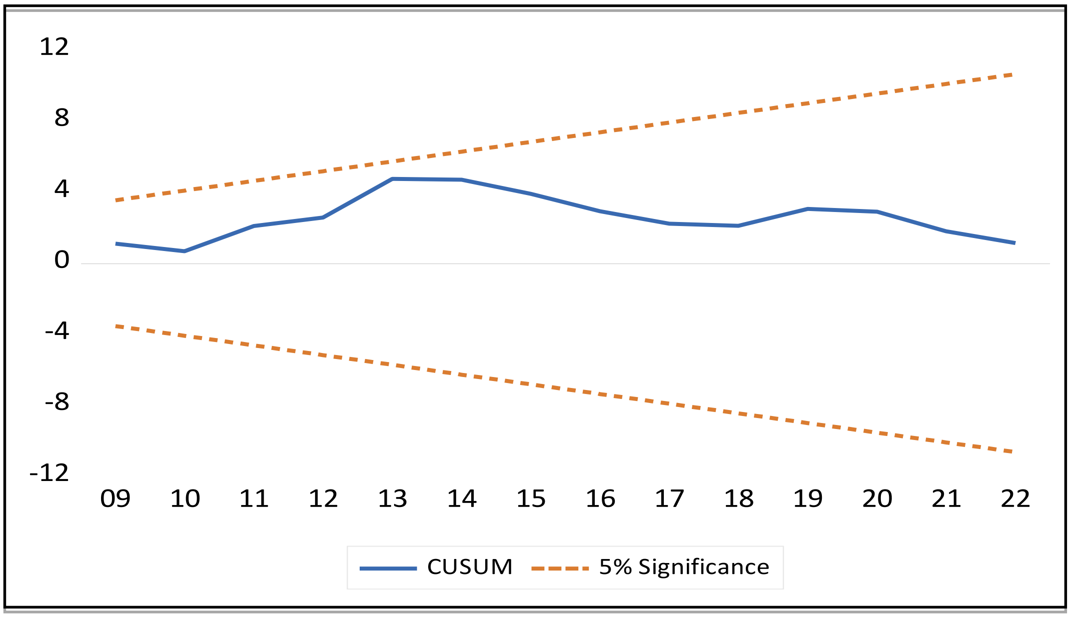

Figure 6: CUSUM Test Plot

IV. DISCUSSION

The ARDL model analysis indicates that the relationship between natural gas supply and CO_2 emissions is somewhat ambiguous. While there is a positive and weakly significant short-run coefficient indicating that an increase in natural gas utilization slightly raises CO_2 emissions. Specifically, a 1-unit increase in NG_SD in the short run increases TCO_2E by 0.148 units. The lagged effect of natural gas supply suggests that past increases in natural gas consumption may lead to a reduction in CO_2 emissions over time. This complex dynamic reflects natural gas's status as a transitional fuel—while it is cleaner than coal and oil, it still emits CO_2, albeit at lower levels [17]. However, the bound test reveals no long-run relationship between natural gas utilization and CO_2 emissions, suggesting that in the long term, other factors may play more decisive roles in reducing emissions, such as the adoption of renewable energy sources and improvements in energy efficiency. The R-squared (0.8665) and Adj. R-squared (0.8093) explains 86.65% and 80.93% variability in TCO_2E by the independent variable indicating an excellent fit. The F-Stat. (15.1480) significant at 1% level indicate the independent variables have a strong impact on TCO_2E with a Durbin-Watson Stat. (2.0250) value close to 2, suggesting no significant autocorrelation in the residuals. The residual and stability diagnostics test indicated residuals are normally distributed, homoscedastic with evidence no serial correlation, while the CUSUMSQ and CUSUM lines falls entirely within the 5% significance bounds throughout the sample period (2009 to 2022) indicated no structural breaks in the model parameters and coefficient implying stability of the model. These findings align with the literature that emphasizes the potential of natural gas as a "bridge fuel" toward a low-carbon economy, but not as a final solution to climate change mitigation [18].

The outcome of the model results indicates that increased domestic natural gas utilization does not significantly contribute to reducing CO_2 emissions. This is consistent with findings from other studies that highlight the need for complementary policies promoting renewable energy and carbon capture technologies to achieve significant long-term reductions in greenhouse gas emissions [19]. Though, natural gas can provide short-term emission reductions compared to other fossil fuels, but further mitigation strategies are needed to achieve sustained environmental benefits.

V. CONCLUSION

The ARDL Model analysed the environmental impact of natural gas utilization, focusing on CO_2 emissions. The results showed that natural gas supply indicated a weak positive relationship with CO_2 emissions in the short run. This suggests that while natural gas is considered cleaner than other fossil fuels, it still contributes to CO_2 emissions. Equally, it indicates that GDP growth is associated with energy-consuming activities leading to emissions from using natural gas and other fossil fuels. Specifically, a 1-unit increase in natural gas supply increases CO_2emissions by 0.15 units. The one-period lagged coefficient for natural gas is negative and weakly significant at the 10% level, suggesting that past increases in natural gas supply could reduce CO_2 emissions in subsequent periods. However, the results showed no significant long-run relationship between natural gas utilization and CO_2 emissions. This means that while natural gas utilization may reduce emissions over time, it is insufficient to produce a sustained long-term reduction in CO_2 emissions. The study recommends for policymakers to promote the use of renewable energies like solar, wind, geothermal, etc., alongside natural gas and carbon capture and storage technology to achieve a sustained CO_2 emission reduction.

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