The Non-Linear Impact of Natural Gas Production on Nigeria's Industrial Sector: Unraveling the Growth Paradox and Investment Dynamics

Inalegwu Akpo Edeh[1]; Dr. Kunle Sofolabo[2]; Aleruchi Boniface Orji[3]

[1]Student; [2]Lecturer; [3]Professor
Emerald Energy Institute, University of Port Harcourt, Port Harcourt, Nigeria

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Abstract: This study investigates the non-linear relationship between natural gas production and Nigeria's economic growth, with industrial output and foreign direct investment (FDI) as moderating factors. Using the Autoregressive Distributed Lag (ARDL) model, the study analyzes time-series data from 2000 to 2022, with GDP as the dependent variable and natural gas production as the key explanatory variable. Industrial output and FDI are incorporated to assess their interactions with gas production and their impact on economic performance. Grounded in the resource-based theory, endogenous growth theory, and the Dutch Disease Hypothesis, the study reveals a long-run equilibrium among the variables. While gas production positively influences GDP, its impact weakens at higher levels without sufficient industrial integration and strategic FDI inflows. Short-run dynamics suggest industrial output and FDI enhance growth, but their interaction with gas production exhibits diminishing returns. Policy recommendations emphasize expanding gas-to-industry infrastructure, reforming regulatory frameworks to promote domestic utilization, and investing in energy transmission to improve industrial efficiency. Fostering research and development (R&D) in gas-based industries can drive innovation, mitigate diminishing returns, and enhance Nigeria's industrial competitiveness for sustainable economic growth.

Keywords: *Natural Gas Production, Economic Growth, Industrial Output, FDI, ARDL Model, Non-Linear Effects.*

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I. INTRODUCTION

Nigeria's natural gas sector has significant potential to drive economic growth. However, the paradox lies in whether increased gas production directly translates into sustained economic expansion. Despite Nigeria's vast gas reserves, economic gains remain inconsistent due to infrastructural gaps, weak industrial linkages, and fluctuating foreign investments [1]. This study explores the non-linear impact of gas production on economic growth by incorporating industrial output and FDI as key moderating factors. The research aims to determine whether Nigeria's gas-led growth strategy effectively enhances industrialization and attracts foreign investments.

II. LITERATURE REVIEW

A. *Conceptual and Theoretical Framework*

Economic growth, driven by energy resources, follows different trajectories depending on how effectively these resources are integrated into productive sectors [2]. Unless complemented by industrialisation and foreign investments, gas production alone may not guarantee economic development. Industrial output represents the extent to which gas resources are converted into economic value, while FDI provides external capital and technology transfer necessary for economic diversification [3].

This study is grounded in the Resource-Based View (RBV) Theory, which argues that resource abundance can either propel or hinder economic development depending on resource management [4]. The Endogenous Growth Theory suggests that investment in productive sectors, including industrialization and FDI inflows, determines

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long-term economic outcomes [5]. Furthermore, the resource curse theory, known as the Dutch Disease Hypothesis, highlights the risk of over-reliance on resource extraction, potentially stifling industrial growth [6].

B. Empirical Review

Empirical findings on the gas-growth nexus remain mixed. While some studies highlight the positive role of gas production in fostering economic growth, others emphasize the structural and institutional challenges that limit its contributions.

Adabor and Buabeng (2021) investigate the asymmetric impact of oil and gas resource rents on Ghana's economic growth from 2010 to 2019. Utilizing the Nonlinear Autoregressive Distributed Lag (NARDL) model, the study reveals that oil resource rent significantly promotes economic growth, supporting the resource blessing hypothesis.

Conversely, gas resource rent exerts a significant adverse effect, aligning with the resource curse hypothesis. The authors argue that the dual-edge impact of natural resource extraction on economic growth necessitates differentiated policy approaches. They recommend promoting oil resource firms in the short term while developing oil and gas resource firms in the long term. This approach aims to harness the positive impacts of oil resource rent while mitigating the adverse effects of gas resource rent. The study underscores the importance of strategic investments and policies tailored to the unique economic contexts of resource-rich countries like Ghana.

Overall, the article provides valuable insights into the complex relationship between natural resource rents and economic growth, highlighting the need for nuanced policy interventions to maximise the benefits of resource wealth while minimizing potential drawbacks.

David I. Stern and Astrid Kander (2012) explored the significant impact of energy services on economic growth, particularly during the Industrial Revolution. The authors extend the Solow growth model to include energy and analyze 200 years of Swedish data. They find that the elasticity of substitution between a capital-labor aggregate and energy is less than unity, indicating that when energy services are scarce, they strongly constrain output growth, resulting in a low-income steady-state.

The study revealed that the expansion of energy services was a significant factor in explaining economic growth in Sweden, especially before the second half of the 20th century. During this period, energy-related innovations and the increase in the quantity and quality of energy played a crucial role in economic development. However, after 1950, labor-augmenting technological change became the dominant factor driving growth, although energy still played a role.

The authors highlighted the historical decline in the energy cost share seen in the Swedish data, which aligns with the broader trend of economic development. They argue that energy's role in long-run growth and the Industrial Revolution is crucial despite its smaller share of production costs in today's advanced economies.

Elizabeth Sendich (2014) provided a comprehensive analysis of the role of natural gas in the industrial sector, mainly focusing on energy-intensive industries. The paper highlights the industrial sector's significant consumption of natural gas, accounting for approximately one-third of total U.S. dry natural gas consumption in 2011.

The study emphasized the potential benefits of expanding oil and gas resources for the industrial sector, noting that increased energy production can lead to more economic activity. However, the paper also pointed out the uncertainties surrounding the industrial sector's future, including technological developments, the types of energy products produced, and legislative and regulatory changes.

These factors can significantly impact the relationship between natural gas supply, prices, and industrial output.

The study evaluated the "shale revolution" and its profound structural shifts in the industrial sector, driven by changes in natural gas content via Natural Gas Liquids (NGLs). The study calls for further statistical testing to determine the existing and evolving relationships between energy and economic factors, particularly in the industrial sector's natural gas supply and price connections.

Overall, the article provided valuable insights into natural gas's importance for the industrial sector, highlighting both the opportunities and challenges associated with increased natural gas production. It underscores the need for continued investment and innovation to harness natural gas's full potential in driving economic growth in energy-intensive industries.

Elizabeth Asiedu, Nana Francois, and Akwasi Nti-Addae (2012) explored the paradoxical situation where Africa, despite being a continent in dire need of capital for development, experiences significant capital flight. The authors highlighted that from 1970 to 2008, the amount of illicit capital flight from Africa far exceeded the combined total of foreign aid and foreign direct investment (FDI) received. This capital flight undermines the efforts to alleviate the capital constraints that hinder economic development, as it reduces the resources available for critical investments in infrastructure, education, and healthcare.

The authors identified several drivers of capital flight, including weak institutional frameworks, poor governance, corruption, and political instability. These factors create an environment where capital is more likely to leave the continent than be invested domestically. The loss of capital through illicit means exacerbates African countries' challenges in achieving sustainable economic growth.

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The authors recommended a range of policy measures to address capital flight. These include strengthening institutional frameworks, improving governance, enhancing transparency, and implementing policies that encourage the retention and productive use of capital within the continent. By addressing these underlying issues, African countries can better harness their capital resources to support development and reduce their reliance on external aid and investment.

Overall, the article illuminates the complex issue of capital flight from Africa and its detrimental impact on the continent's development. It underscores the need for comprehensive policy measures to curb capital flight and ensure that capital inflows are effectively utilized to support sustainable growth.

John C. Anyanwu's (2012) study on FDI in African countries provides several key implications for policymakers. Firstly, the positive relationship between market size and FDI inflows suggests that African countries should focus on expanding their domestic markets. This can be achieved by improving infrastructure, increasing consumer purchasing power, and fostering economic growth, creating more extensive and attractive markets for foreign investors.

Secondly, the study highlights the importance of trade liberalization in attracting FDI. African countries should consider reducing trade barriers, simplifying customs procedures, and entering into trade agreements that facilitate easier access to international markets. By doing so, they can create a more open and inviting environment for foreign investments.

Thirdly, the findings emphasize the need for strengthening institutional quality. Investing in legal and regulatory frameworks, enhancing the rule of law, reducing corruption, and ensuring transparent governance can create a more favourable environment for FDI. Strong institutions are crucial for attracting and retaining foreign investments.

Additionally, the study underscores the importance of effectively managing and leveraging natural resources.

Resource-rich countries should implement policies that ensure sustainable resource extraction, fair distribution of resource revenues, and reinvestment in other sectors of the economy. This approach can help attract FDI and support long-term economic growth.

Furthermore, the positive impact of agglomeration effects suggests that promoting the development of industrial clusters can be beneficial. By creating special economic zones, providing incentives for businesses to locate in specific areas, and investing in infrastructure, African countries can develop attractive hubs for foreign investors.

Lastly, the study's observation of regional differences in FDI inflows implies that regional cooperation and integration can be advantageous. By working together, countries in regions like East and Southern Africa can create larger, more integrated markets that are more appealing to foreign investors. This regional approach can enhance the overall attractiveness of the continent for FDI.

Overall, Anyanwu's findings provide a comprehensive roadmap for African policymakers to create an enabling environment for FDI. By focusing on market expansion, trade liberalization, institutional strengthening, resource management, industrial clustering, and regional cooperation, African countries can attract and retain more FDI, thereby supporting sustainable economic growth and development.

Despite these insights, the extent of non-linear effects in the gas-industrial output-FDI nexus remains underexplored in Nigeria’s context. Existing studies have primarily focused on linear relationships, overlooking potential threshold effects and diminishing returns associated with increased gas production. Understanding these interactions is crucial for policymakers seeking to optimize gas sector investments for long-term economic development.

Thus, this study fills the gap by investigating the non-linear impact of gas production on economic growth, incorporating interaction effects with industrial output and FDI. This approach provides a more comprehensive understanding of the conditions under which gas investments yield optimal economic benefits.

III. MATERIALD AND METHOD

A. Data and Variables

This study employs annual time-series data from 2000 to 2022 from the Central Bank of Nigeria (CBN), the World Bank, and the Nigerian National Petroleum Corporation (NNPC). The key variables include Gross Domestic Product (GDP) as the dependent variable, Gas Production output as the independent Variable, and foreign direct investment (FDI) and Industrial output as control Variables.

B. Model Specification

To examine the short-run and long-run relationships, the study employs the ARDL model following the works of Pesaran, M. H., Shin, Y., & Smith, R. J. (2001).

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=0}^{q} \beta_j G_{t-j} + \sum_{k=0}^{r} \gamma_k X_{t-k} + \ \dots . \ + \epsilon_t \tag{1}$$

Where:

Y_t, = the dependent variables lagged by i Period.
G_{t-j} = independent variables lagged by j period
X_{t-k} = control variables lagged by k period
(α_i), (β_j) and (γ_k) = The coefficients of the lagged variables.

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X_t = Represents control variables
(ϵ_t) = is the error term.

C. Estimation Technique

The Augmented Dickey-Fuller (ADF) test is a key unit root test in time-series econometrics, used to determine whether a variable is stationary or contains a unit root. Ensuring stationarity is essential to avoid spurious regression results. Once stationarity is confirmed, the Autoregressive Distributed Lag (ARDL) bounds testing approach examines the long-run relationships among variables [12]. Unlike traditional cointegration techniques, ARDL accommodates both I(0) and I(1) variables, making it a flexible tool for time-series analysis. The bounds test uses an F-test to determine whether a long-run relationship exists, with outcomes depending on whether the test statistic exceeds, falls below, or lies between critical bounds.

If a long-run relationship is confirmed, the Error Correction Model (ECM) is estimated to capture both short-term and long-term dynamics. The ECM adjusts for short-run deviations from long-run equilibrium by incorporating an error correction term. This term reflects the speed of adjustment toward equilibrium after a shock [13].

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{q} \delta_j \Delta X_{t-j} + \lambda ECM_{t-1} + \epsilon_t \quad (2)$$

Where:
ΔY_t = the change in the dependent variable (e.g., GDP or natural gas production),
ΔY_{t-i} = the change in the independent variable (e.g., gas production, FDI, GFCF, etc.) at lag j,
ECM_{t-1} = the lagged error correction term from the long-run equilibrium relationship representing the deviation from equilibrium,
λ = the coefficient of the error correction term,
α_0 = the constant term,
β_i and δ_j = the coefficients of the short-run dynamics
p and q = the maximum lag orders of the dependent and independent variables,
ϵ_t = the error term.

A significant and negative ECM coefficient indicates how quickly the system returns to equilibrium after a shock. Diagnostic tests such as the Breusch-Godfrey test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, and the Jarque-Bera test for normality are performed to validate model robustness. These tests help ensure that estimation results are statistically reliable.

IV. RESULTS

A. Descriptive Statistics

The result in Table 1 indicates that the variables are normally distributed, as shown by the Jarque-Bera (JB) statistics with a p-value > 0.05.

Table 1: Descriptive Statistic Result

	GDP	GAS_PROD	FDI	IND_OUT
Mean	333.0534	34194.11	3.93087	32.87435
Median	375.7457	38411	3.31	29.72175
Maximum	574.1838	49947.29	8.84	64.40968
Minimum	69.17145	12460	-0.19	9.637935
Std. Dev.	156.9997	12197.16	2.616712	17.59244
Skewness	-0.450042	-0.392306	0.442	0.37223
Kurtosis	1.895209	1.700859	2.115407	1.927141
Jarque-Bera	1.946103	2.207409	1.498794	1.634195
Probability	0.377928	0.33164	0.472651	0.441712
Sum	7660.228	786464.5	90.41	756.1101
Sum Sq. Dev.	542275.7	3.27E+09	150.638	6808.867
Observations	23	23	23	23

Source: E-Views 12

B. Stylized Facts

- ➢ *The Interactions of Gas Production, FDI, Industrial Output and GDP in Nigeria*

The stylized facts presented in Figure 1 below highlight the trends and interactions among Nigeria's Gross Domestic Product (GDP), Gas Production (Gas_Prod), Foreign Direct Investment (FDI), and Industrial Output (Ind_Out) over time. The figure also marks key economic and geopolitical events that may have influenced these variables.

Nigeria's GDP grew steadily until 2014 but declined] during the 2016 recession. 2008 Global

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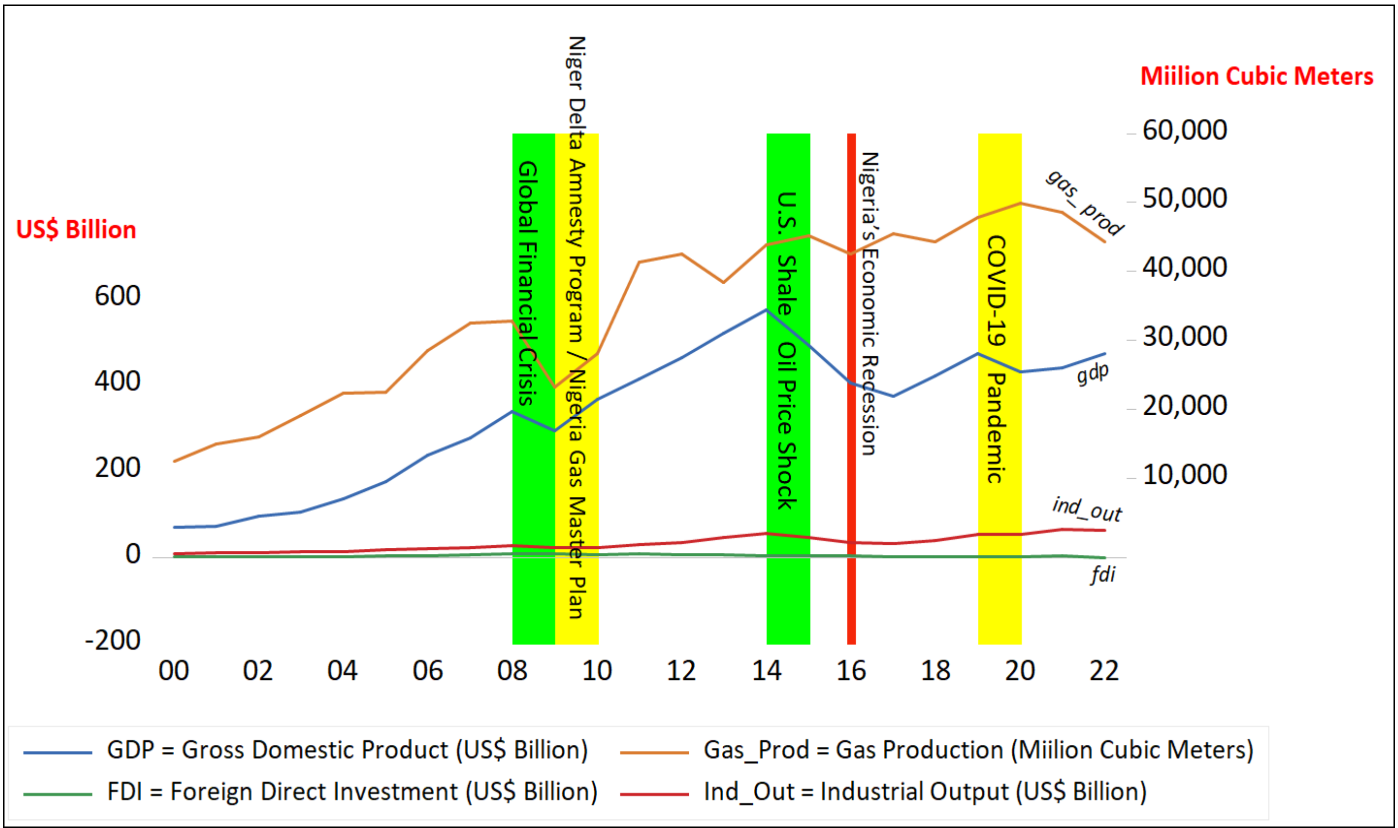

Fig 1: Annual Trend of the Interactions of Interactions of Gas Production, FDI, Industrial Output and GDP in Nigeria

The Financial Crisis had minimal impact, while the 2014 U.S. shale oil price shock and the COVID-19 pandemic (2020) disrupted growth. The Niger Delta Amnesty (2009) and Gas Master Plan spurred GDP, but structural challenges persist post-recession.

Gas production follows a similar trajectory, rising steadily from 2000 to 2014 before experiencing some fluctuations. The U.S. shale oil price shock 2014 likely contributed to this volatility, as global oil and gas markets were disrupted.

The COVID-19 pandemic in 2020 also appears to have caused a decline in gas production, reflecting the impact of reduced global demand and economic slowdowns.

FDI exhibits a relatively flat trend, with minor fluctuations but no significant growth. It appears to be negatively affected by major global and domestic economic shocks, such as the Global Financial Crisis (2008) and

Nigeria's economic recession (2016). The lack of a strong upward trend suggests persistent structural challenges in attracting foreign investment into Nigeria's economy.

Industrial output gradually increases over time but at a much slower rate compared to GDP and gas production. This trend could indicate that while Nigeria has experienced overall economic growth, industrial development has lagged, possibly due to structural inefficiencies, weak infrastructure, and an overreliance on oil and gas.

The key events marked in the figure provide further context. The Niger Delta Amnesty Program and Nigeria Gas Master Plan (2009–2010) appear to coincide with a period of sustained GDP and gas production growth, suggesting a positive effect of these policies. Conversely, global and domestic economic crises, including the Global Financial Crisis (2008), the U.S. Shale Oil Price Shock (2014), and the COVID-19 pandemic (2020), are associated with downturns in economic activity.

The figure illustrates the intricate relationship between Nigeria's economic growth, natural gas production, foreign investment, and industrial output. While GDP and gas production have grown significantly, industrial output and FDI remain relatively stagnant, indicating a potential growth paradox where increased resource production does not necessarily translate into broader industrial and economic development.

C. ARDL Model

- *Model Specification*

Find below the specified ARDL equation for the model

$$GDP_t = \alpha_0 + \sum_{i=1}^{p} \beta_0\, GDP_{t-i} + \sum_{j=0}^{q_1} \beta_{1j}\, Gas\_Prod_{t-j} + \sum_{j=0}^{q_2} \beta_{2j}\, FDI_{t-j} + \sum_{j=0}^{q_3} \beta_{3j}\, Ind\_Out_{t-j} + \sum_{j=0}^{q_4} \beta_{4j}\, Int\_FDI_{t-j} + \sum_{j=0}^{q_5} \beta_{5j}\, Int\_Ind\_Out_{t-j} + \varepsilon_t \quad (3)$$

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Where:
GDP = Gross Domestic Product
Gas_Prod = Gas Production in billions of cubic meters
FDI = Foreign Direct Investment in US billion
Ind_Out = Industrial Output in US billion
Int_ FDI= $(GAS\_PROD \ x \ FDI_{t-j})$ The interaction term of FDI and Gas_Prod)
Int_Ind_Out = $(GAS\_Prod_{t-j} \ x \ Ind\_Out_{t-j})$ The interaction terms of Ind_Out and Gas_Prod
α_0 = Constant term
$\beta_0, \beta_1, \beta_2, \beta_3, . \beta_5$ = the coefficients of the lagged variables.
$j, p, q_1, q_2, q_3, .. q_5$ = lag order of variables
ε_t = Error term

➢ *Stationarity Test and Lag Length Selection*

The Augmented Dickey-Fuller (ADF) unit root test was used to test whether the variables were stationary and their order of integration. The unit root test result in Table 2 confirms the stationarity of the variables with their order of integration.

To examine the long-run cointegration between these variables, the order of lags was applied in the first differenced variables, as in equations 1. As Pesaran et al. (2001) suggested, AIC was used to determine the optimum lag selection for the ARDL model. This was examined in the presence of the trend and intercept. The Unrestricted Vector Autoregressive (UVAR) Lag Length Selection Criteria results give the optimal lag length of 1 and 2 for the variables, as in Table 2.

Table 2: Unit Root Test and Lag Length Selection Results

S/N	Variable	ADF Unit Root Test Result	Order of Integration	Optimal Lag Length
1	GDP	Stationary at 1st Diff C only	Order of integration I(1)	1
2	Gas_Prod	Stationary at 1st Diff C only	Order of integration I(1)	1
3	FDI	Stationary at 1st Diff C only	Order of integration I(1)	1
4	Ind_Out	Stationary at Levels @ C only	Order of integration I(0)	2
	Note: C – Intercept C & T Intercept & Trend			

Source: EViews 12

D. ARDL Bounds Test Result

➢ *Cointegration Test Result*

The bounds test result in Table 3 confirms a long-run relationship, with the F-statistic (21.49) exceeding the upper bound critical values at the 1% level. This indicates that gas production, industrial output, and FDI interact significantly to influence GDP.

Table 3: ARDL Bound Test Result

F-Bounds Test	**Null Hypothesis: No levels Relationship**			
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n = 1000		
F-statistic	21.49	10%	2.26	3.35
K	5	5%	2.62	3.79
		2.50%	2.96	4.18
		1%	3.41	4.68

Source: EViews 12

➢ *Long Run Dynamics*

The ARDL bounds test results confirm the existence of a long-run relationship between GDP and the explanatory variables, as indicated by the F-statistic of 21.49, which exceeds the upper bound critical values at all conventional significance levels. This suggests that gas production, industrial output, and foreign direct investment (FDI) collectively influence Nigeria's economic growth dynamics in the long run.

In the long-run equation, as shown in Table 4, gas production has a positive and statistically significant impact on GDP, with a positive and highly significant coefficient of 0.011 (p = 0.0003), indicating that a 1% increase in gas production leads to a 0.011% increase in GDP. This finding highlights the role of natural gas as a critical economic driver, though the relatively small magnitude suggests that other factors may be mediating its overall contribution to growth. This is consistent with Chang, T., & Martinez-Chombo, E. (2016), highlighting that increased natural gas consumption positively impacts economic development [14].

Industrial output also significantly affects GDP, with a positive and highly significant coefficient of 34.15 (p = 0.0003), reinforcing the argument that the industrial sector is pivotal in transforming gas production into tangible economic benefits. This result is consistent with the World Bank (2020), where the report explores the viability of industrialization as a development strategy in Sub-Saharan

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Africa, highlighting the role of industrial activities in job generation, poverty reduction, and sustainable growth. The authors emphasize the importance of industrialization in driving economic growth in developing countries [16], [17], [18].

Table 4: Estimated Long Run Coefficients for the Model

Levels Equation				
Case 3: Unrestricted Constant and No Trend				
Variable	**Coeff.**	**Std. Error**	**t-Stat.**	**Prob.**
GAS_PROD	0.011	0.0023	4.82	0.0003
FDI	-14.05	14.4287	-0.97	0.3481
INT_FDI	0.0005	0.0004	1.447	0.1717
IND_OUT	34.147	7.0204	4.864	0.0003
INT_IND_OUT	-0.0006	0.0001	-4.37	0.0008

Source: EViews 12

Conversely, the coefficient for FDI is negative (-14.04) and statistically insignificant (p = 0.3481), suggesting that foreign direct investment alone does not directly contribute to economic growth in the long run. This result is consistent with the works of Faheem, G. B., & Siddiqui, D. A. (2020), who concluded that countries with poor institutional qualities to curb structural inefficiencies [15]. However, the interaction term between FDI and gas production (INT_FDI) is positive (0.000526) but not statistically significant (p = 0.1717), indicating that while FDI may enhance the impact of gas production, the effect is not robust enough to be conclusive. In contrast, the interaction between industrial output and gas production (INT_IND_OUT) has a negative and highly significant coefficient (-0.000647, p = 0.0008), implying that excessive reliance on gas production without proportional industrial capacity may lead to diminishing returns, aligning with the resource curse hypothesis.

➢ *Short Run Dynamics*

The short-run estimates from the ECM regression results in Table 5 provide key statistical insights into the behaviour of GDP in response to changes in gas production (Gas_Prod), industrial output (Ind_Out),]and foreign direct investment (FDI). The error correction term (CointEq(-1) = -0.3989, p = 0.0000) is negative and statistically significant at the 1% level, confirming the presence of a long-run relationship among the variables. The magnitude of -0.3989 suggests that about 39.9% of any disequilibrium in GDP is corrected in each period, implying a moderate speed of adjustment toward long-run equilibrium. The statistical significance indicates that deviations from equilibrium are not random but follow a predictable pattern, reinforcing the validity of the ARDL approach for estimating short-run and long-run effects.

Table 5: Error Correction Representation for the Model

ECM Regression				
Case 3: Unrestricted Constant and No Trend				
Variable	**Coeff.**	**Std. Error**	**t-Stat.**	**Prob.**
C	-134.78	10.750	-12.54	0.000
D(FDI)	-12.24	1.564	-7.83	0.000
D(INT_IND_OUT	-0.0002	2.2E-05	-7.83	0.000
CointEq(-1)*	-0.399	0.030	-13.36	0.000

Source: EViews 12

The short-run coefficient of FDI (D(FDI) = -12.24241, p = 0.0000) is negative and statistically significant, implying that immediate inflows of FDI reduce GDP in the short term. This counterintuitive result may be attributed to capital flight, repatriation of profits by foreign investors, or inefficiencies in FDI absorption within the economy. While foreign investments have the potential to enhance long-term growth, their short-run effects may be disruptive due to the restructuring costs associated with integrating foreign capital into the domestic economy.

The interaction term between gas production and industrial output (D(INT_IND_OUT) = -0.000172, p = 0.0000) is negative and statistically significant, reinforcing non-linear effects in the relationship between industrial activity and economic growth. This indicates that while industrial output is a key driver of long-term growth, excessive or inefficient expansion of gas-dependent industries in the short run may lead to diminishing returns. This could be due to supply chain bottlenecks, infrastructural constraints, or market saturation effects that prevent additional industrial output from generating proportional economic gains. The non-linearity suggests that policy interventions should aim to optimize rather than expand industrial activity, ensuring that the industrial sector remains efficient and well-integrated with gas infrastructure development.

➢ *Model Diagnostics Test*

The model passes all diagnostic tests, meeting the ARDL model assumption of normality, Homoscedasticity, and no autocorrelation among residuals, as shown in Figures 2, 3, and 4 and Tables 6 and 7, ensuring robust and reliable estimations.

- *Histogram Normality Test*

The Jarque-Bera test statistic is 1.6040, with a significantly higher probability value of 0.4484, as shown in Figure 2. For the p > 0.05, we fail to reject the null hypothesis, which states that the residuals are normally distributed.

This result satisfies the normality assumption at a probability more significant than the 5% significance level, suggesting that it provides a comprehensive and statistically sound representation of the relationships under investigation.

- *Breusch-Godfrey Serial Correlation LM Test*

The results of the Breusch-Godfrey Serial Correlation LM Test for the Model in Table 6 indicate that the Model has an F-statistic of 3.114274 and a p-value of 0.0848. The p-value above 0.05 indicates that the null hypothesis of no serial correlation cannot be rejected.

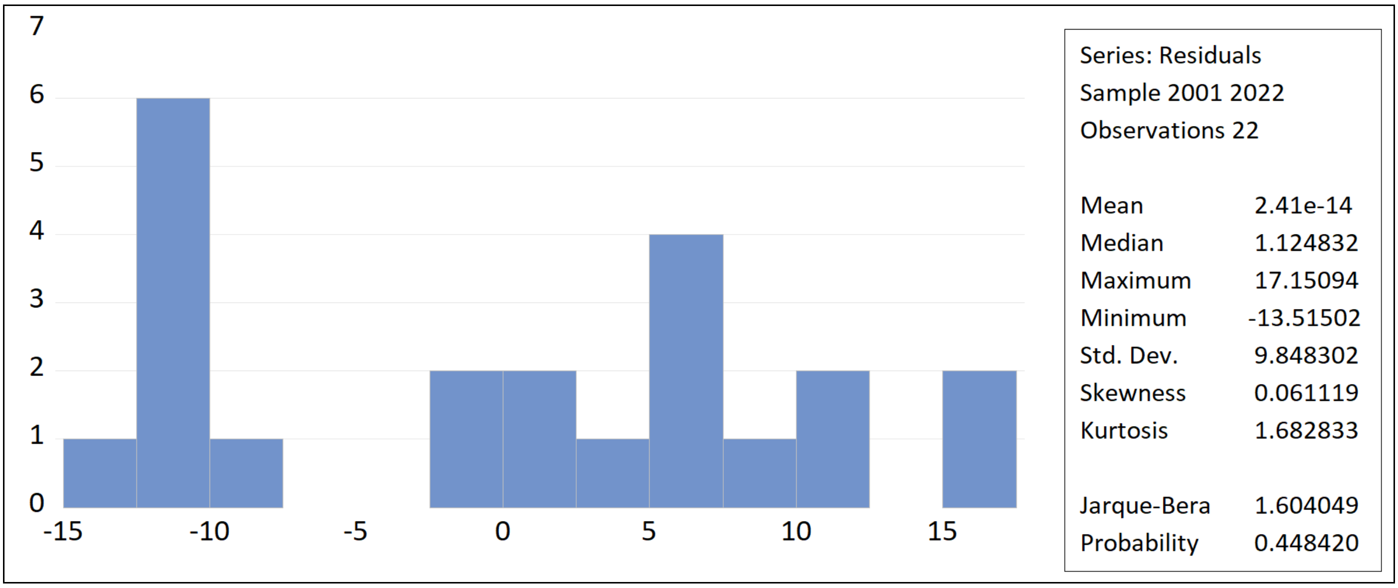

Fig 2: Normality Test Results for the modelt
Source: EViews 12

Table 6: ARDL Breusch-Godfrey Serial LM Test Result

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	3.1142	Prob. F(2,11)	0.0848
Obs*R-squared	7.9536	Prob. Chi-Square(2)	0.0187
Durbin Watson	2.2997		
Status	**No Autocorrelation Among Residuals**		

Source: EViews 12

However, the Obs*R-squared statistic is 13.43601 with a p-value of 0.0012, which indicates significant evidence of serial correlation. Additional diagnostic tests, such as the Durbin-Watson statistic, were employed to reconcile these results and ensure robust conclusions. The ARDL model yields a DW statistic of 2.2997, which is also close to 2, further supporting the absence of significant serial correlation.

- *Heteroskedasticity Test:*

Table 7 shows that the Model has an F-statistic of 3.2687 (p = 0.0605) and an ObsR-squared of 19.0812 (p = 0.1619).

Table 7: Heteroskedasticity Test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	**1.5478**	**Prob. F(8,13)**	**0.2324**
Obs*R-squared	10.7325	Prob. Chi-Square(8)	0.2173
Scaled explained SS	1.2794	Prob. Chi-Square(8)	0.9958
Status	Residuals are Homoscedastic		

Source: EViews 12

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The F-statistics and the ObsR-squared probability indicate values above the 5% significance threshold, suggesting no evidence of heteroskedasticity.

- *Stability Test*

The CUSUM and CUSUM of Squares tests were utilized to assess the stability of model parameters over the sample period. The CUSUM and CUSUMQ plots in Figures 3 and 4 indicate that the Model remained within the 5% critical lines throughout the sample period. This outcome signifies that the model's parameters are Stable over time, with no evidence of structural instability.

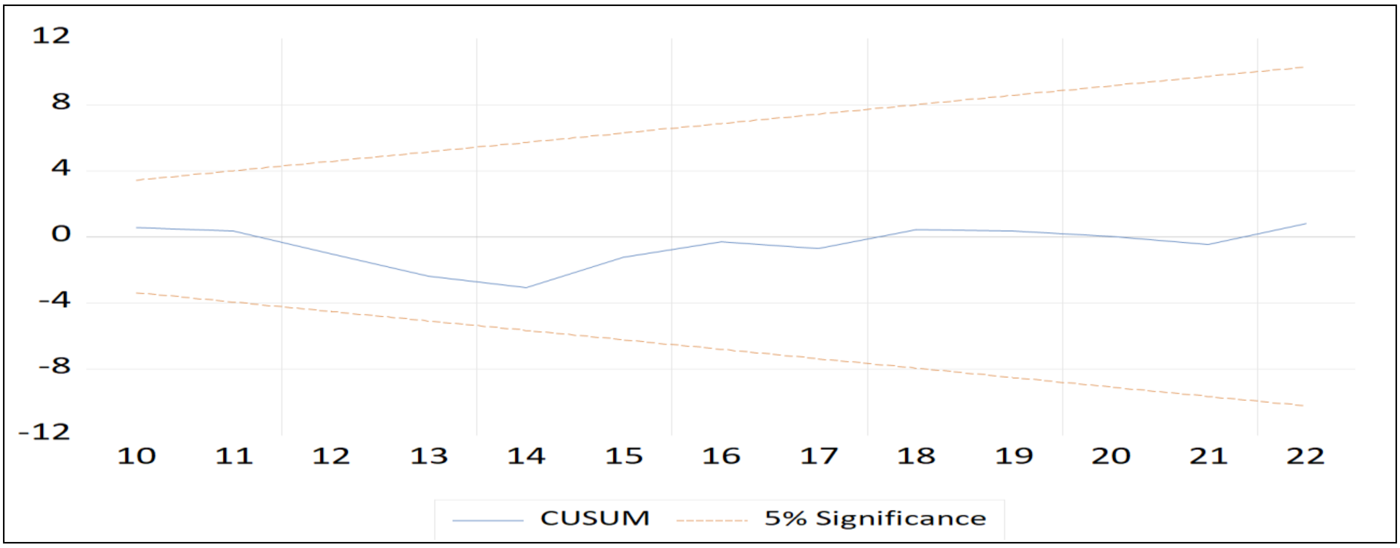

Fig 3: CUSUM Stability Test Result
Source: EViews 12

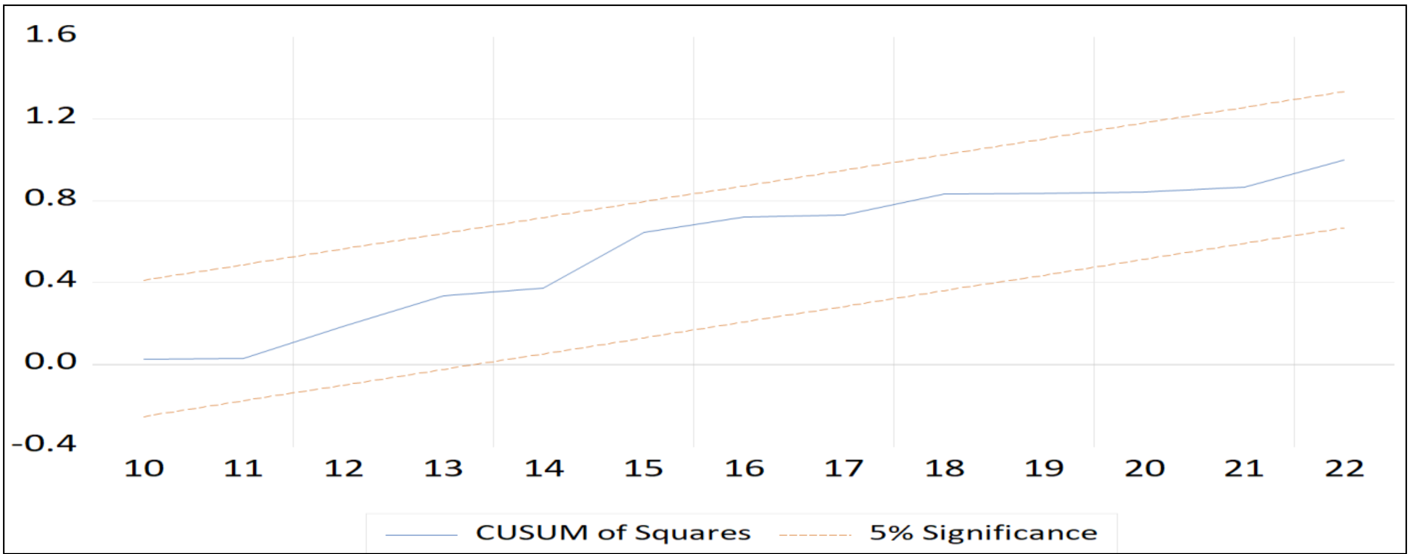

Fig 4: CUSUM of Squares Stability Test Result
Source: EViews 12

- *Model Fit and Reliability*

The ECM regression exhibits high explanatory power, with an R-squared value of 0.9557 and an adjusted R-squared value of 0.9483, indicating that the model explains approximately 95.6% and 94.8% of the variations in GDP, respectively. The F-statistic (129.3711, p = 0.0000) confirm the overall significance of the model. These robustness checks affirm the reliability of the estimated relationships and reinforce the validity of the identified short-run dynamics.

V. DISCUSSIONS OF RESULTS

Overall, these results underscore the importance of industrial development as a channel through which gas production can drive sustainable economic growth. While gas production positively influences GDP, its impact is more pronounced when complemented by industrial expansion.

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The findings also highlight potential inefficiencies in FDI inflows, suggesting that policy efforts should focus on improving the economy's absorptive capacity to maximize foreign investment benefits. Lastly, the negative interaction between industrial output and gas production suggests the need for strategic policies that ensure balanced industrialization, preventing overreliance on gas without adequate productive capacity.

The Negative interaction terms in the long-run equation indicate a non-linear relationship between gas production, industrial output, and economic growth. Specifically, the interaction between industrial output and gas production (INT_IND_OUT) has a negative and highly significant coefficient (-0.000647, p = 0.0008), suggesting that while industrial output is a strong driver of GDP, its marginal contribution diminishes as gas production increases beyond a certain threshold. This finding implies that excessive gas production without a corresponding increase in industrial capacity leads to diminishing economic returns, consistent with resource dependency limiting broader economic diversification.

Similarly, the interaction term between gas production and foreign direct investment (INT_FDI) is positive (0.000526) but statistically insignificant (p = 0.1717), suggesting that the complementary effects of FDI on gas-driven growth are not robust. This insignificance could indicate that foreign investment does not always translate into productive capital formation within the gas sector, potentially due to inefficiencies in investment absorption, capital flight, or misalignment between FDI inflows and industrial needs.

These results highlight a fundamental growth paradox: While gas production contributes positively to economic growth, overemphasising gas extraction without sufficient industrial capacity can lead to economic inefficiencies. The negative interaction between industrial output and gas production suggests that increased gas production may fail to generate proportional economic benefits beyond a certain point unless industries effectively utilize the gas resources. This aligns with the Dutch Disease hypothesis, which warns that resource booms can crowd out other productive sectors, leading to structural imbalances in the economy.

Policy efforts should focus on fostering industrial expansion alongside gas production growth to mitigate these non-linear effects. This requires infrastructure, technology, and workforce development investments to integrate gas resources into the broader economy efficiently. Additionally, targeted policies should aim to enhance the absorptive capacity of FDI, ensuring that foreign investments contribute meaningfully to industrialization and economic diversification. Without such interventions, the economy risks falling into a pattern where gas production increases, but its incremental benefits to GDP decline, leading to suboptimal long-term growth outcomes.

VI. CONCLUSIONS

This study highlights the complex relationship between natural gas production, industrial output, and foreign direct investment (FDI) in Nigeria's economic growth. In the long run, gas production and industrial output positively impact GDP, but their interaction suggests diminishing returns beyond a certain threshold. FDI, however, does not significantly contribute to long-term growth. In the short run, FDI negatively affects GDP, indicating initial economic disruptions, while the interaction between industrial output and gas production also shows non-linear effects. The strong error correction term suggests that the economy can adjust to deviations from long-run equilibrium.

The following recommendations are required to enhance the integration of the gas sector with industrial growth: Policymakers should prioritize expanding gas-to-industry infrastructure to ensure a steady supply for the manufacturing sector. Addressing the negative interaction between gas production and industrial output requires regulatory reforms encouraging domestic utilization over exports. Strengthening public-private partnerships (PPPs) in gas-based industrial projects can drive long-term economic benefits by fostering investment and operational efficiency.

Reforming FDI policies is essential to shifting investments from extractive industries toward gas-based industrialization, including gas-to-power and petrochemical industries. Policies should promote stronger linkages between foreign firms and domestic enterprises to enhance knowledge transfer and local value addition. Furthermore, performance-based incentives for FDI should be introduced to ensure that foreign investments contribute meaningfully to long-term economic growth and industrial development.

Addressing structural constraints in industrialization requires investment in energy transmission and distribution networks to reduce reliance on inefficient energy alternatives. Industrial efficiency in gas utilization must be improved to mitigate diminishing returns from gas production. Promoting research and development (R&D) in gas-based industries can foster domestic innovation and productivity, ensuring a more sustainable and competitive industrial sector.

Future research should conduct a sectoral analysis of gas utilization to assess its impact on manufacturing, power generation, and transportation industries. This approach would provide insights into optimal resource allocation and enhance economic efficiency.

Additionally, investigating the role of regulatory frameworks in shaping gas sector performance could offer valuable policy recommendations for improving governance, enhancing investor confidence, and reducing inefficiencies. Comparative analyses of other gas-producing nations may highlight the best practices.

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Furthermore, exploring the non-linear effects of gas production using advanced econometric techniques, including threshold regression and machine learning models, can help identify optimal production levels. Understanding the thresholds at which gas production shifts from beneficial to detrimental would enable policymakers to formulate evidence-based strategies for sustainable economic growth, resource management, and infrastructure development.

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