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Asymmetric Effects of Natural Gas Consumption by GENCOs on the Nigerian Economy: A Nonlinear ARDL Approach

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Abstract: This research article examined the correlation between natural gas usage by power generation firms and economic growth in Nigeria. The study analyzed many factors, including liquefied petroleum gas usage, industrial gas consumption, and gas consumption for electricity production, and their effects on gross domestic product (GDP). Data on a quarterly basis from 2010 to 2020, sourced from reputable entities such as the Central Bank of Nigeria, Gas Exporting Countries Forum, and the United Nations, were employed for the analysis. The study investigation utilized the Nonlinear Autoregressive Distributed Lag (NARDL) approach. The results indicated that gas usage substantially affected Nigeria's GDP in short term and long run. The research indicated that a 1% growth in gas utilization by electric power plants and LPG usage positively correlated with a 1.04% and 16.64% rise in Nigeria's GDP, respectively. A 1% reduction in industrial gas usage would result in a 19.95% decline in Nigeria's GDP. The findings demonstrated that augmenting gas use in power generating influenced the GDP. Based on the study, it is advised that the Nigerian government undertake steps to increase the consumption of LPG and natural gas for industrial applications and electricity generation to foster economic growth.

Keywords: GDP, NARDL, Natural gas consumption, Economic growth.

I. Introduction

Africa contributes less than 4% of the total global energy-related CO_2 emissions, notwithstanding the scenario applied. Under current policies. The worldwide mean temperature is anticipated to increase by 2°C by 2050 (IEA Energy Transition Report, 2023). However, this increase would likely be higher in North Africa, with median temperatures climbing by 2.7°C, which could lead to an estimated 8% reduction in African GDP by mid-century. Over 5,000 billion cubic meters (bcm) of natural gas have been discovered in Africa yet remain undeveloped. These resources would provide an extra 90 bcm of gas per year by 2030, which could be crucial for industries which include fertilizer production, steel, cement, and water desalination (Energy Information Administration, 2018). Over the next 30 years, using these gas reserves could generate approximately 10 gigatonnes of cumulative CO_2 emissions. If added to Africa's current emissions, this would only increase its share of global emissions to 3.5% (IEA, 2022). This highlights the importance of developing these gas resources to support economic growth while aligning with climate goals for a low-carbon future.

In Nigeria, where consistent electricity generation is essential for industrial expansion, employment creation, and general economic stability, the power industry has important role to play in the development of the country's economy. Among the different energy sources utilized in the nation to generate power, natural gas is the most common fuel. The Nigerian Electricity Regulatory Commission (NERC) reports that natural gas powers the majority of the thermal plants run by generation companies (GenCos), accounting for over 75% of the nation's electricity generation, with hydropower plants providing about 25% of the total power generated (NERC, 2023). Figure 1 depicts the percentage contributions of the two energy sources (gas and hydro) to Nigeria's overall energy generation from 1980 to 2015. All the same, Nigeria is still beset by severe power outages, and regular failures of the national system result in large-scale financial losses. Due to inadequate gas supplies and inefficient infrastructure, the nation's installed power capacity, which is expected to be 12,660 megawatts (MW), is drastically underutilized, with effective generation hovering at 4,544 MW (NERC, 2023).

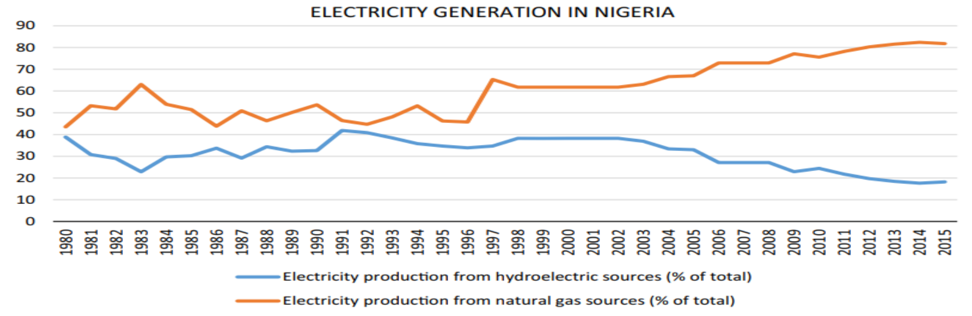


Figure 1: Electricity generation in Nigeria, 1980 – 2015; Source: Oyeleke and Akinlo (2019)

This inadequacy in electricity generation, primarily powered by natural gas, has had far-reaching consequences on Nigeria's GDP (Gross Domestic Product). Several studies have highlighted a strong correlation between consumption of energy and the growth of the economy, especially in developing countries (IEA, Africa Energy Outlook, 2022). For Nigeria, where energy remains a key input for industries and households, the consumption of natural gas by GenCos plays an integral role in driving productivity across sectors (Malami et al., 2024). It is estimated that Nigeria loses approximately $25 billion annually, or about 6% of its GDP**,** due to unreliable electricity (World Bank, 2021). About 55% of Nigerian citizens has access to the electricity grid, which can meet just 30% of the country's total electricity demand. The population of Nigeria is estimated at over 200 million citizens, although its per capita electricity consumption is incredibly low at 151 kWh due to a combination of poor electrical generation and a high population. The averages for Africa and sub-Saharan Africa are 550 kWh and 370 kWh, respectively, and this number is much lower (Owebor et al., 2021). The economy is impacted asymmetrically by GenCo's struggles with irregular gas supply, with periods of gas shortages leading to significant declines in GDP growth (Ummalla and Samal, 2019). Nigeria has the biggest energy access deficit in the world, with 43% of Nigerians translating to 85 million citizens lack access to public electricity. This has significant implications for economic growth.

Figure 2: Nigeria's electricity access statistics; Source: World Bank, 2021

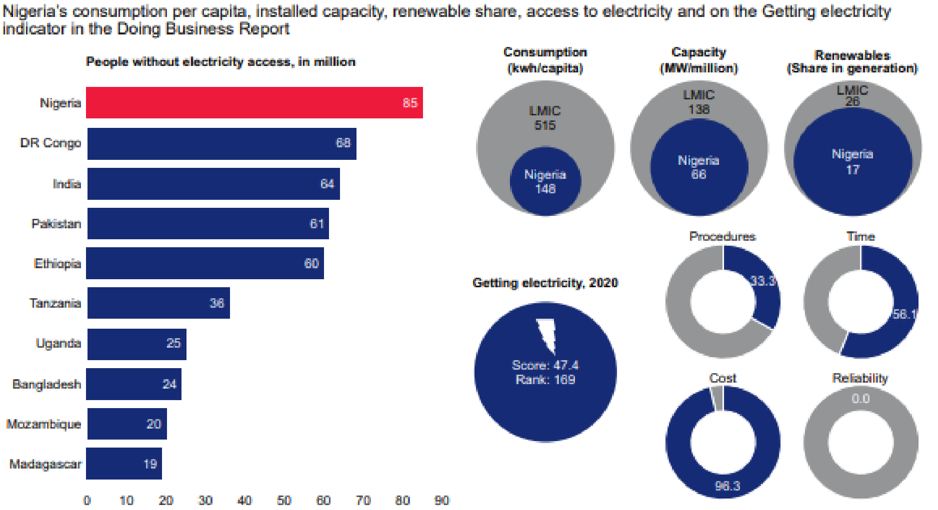


Figure 2: Nigeria's unreliable electricity access statistics; Source: World Bank, 2021

As of 2018, Nigeria accounted for 29% of the oil reserves and 21% of the gas reserves on the continent, making it a significant player in the energy industry (Udoudo et al, 2023). The production-to-reserve ratio of Nigeria is below 1%, the industry is still mostly undeveloped even though the nation is ranked ninth in terms of gas reserve globally (Nwaoha and Wood, 2014). Nigeria is number one in terms of gas reserve holder in Africa and the number three gas producer on the continent, with confirmed natural gas reserves of 209.2 trillion cubic feet (tcf) as of January 1st, 2024, of which 139.4 tcf are considered recoverable (Obada et al., 2024).

In light of this, it is critical to comprehend the asymmetric consequences that GenCos's natural gas consumption has on Nigeria's economy. There are no studies that applied the nonlinear dynamics of gas consumption by power plants and its disproportionate effects on GDP, despite previous research focusing on energy consumption and industrial production. Using NARDL (Nonlinear Autoregressive Distributed Lag) approach, this research will investigate the effects of increase and decrease in GenCos' natural gas consumption on Nigeria's GDP (Ozcan and Ozturk, 2019). This study will provide further insight into the degree to which stabilizing the gas supply and reforming energy policies may support long-term economic development by capturing these asymmetric impacts (Solarin and Ozturk, 2016). The study is particularly relevant in light of the Federal Government of Nigeria's ongoing efforts to boost domestic natural gas usage under the "Decade of Gas" strategy. The link between GENCO gas consumption and economic development may provide policymakers with valuable data to improve Nigeria's energy mix and increase the efficiency of the power sector (Nwabueze and Joel, 2022).

A large portion of the literature on economics examined the causal relationship between growth of the economy and energy use. There is still contention with regard to the nature of this link. While some empirical research see the opposite, others suggest a unidirectional causal relationship between growth of the economy and power use. Furthermore, a few research has indicated no causative relationship at all, showing a neutral association between energy consumption and economic growth, while other studies have discovered evidence of a bidirectional causal link between the two variables (Akinlo, 2009).

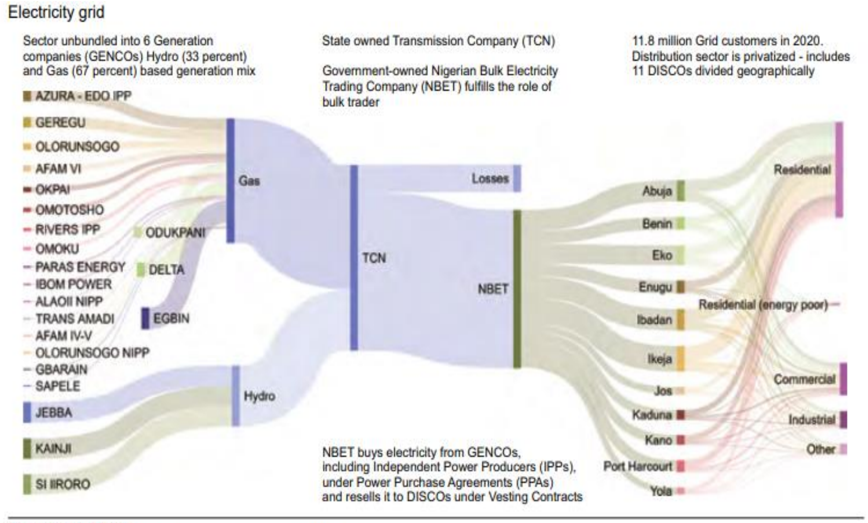
A review of the literature that examines current theories and empirical research on the connection between energy use and growth of the economy will come after this introduction. The NARDL strategy and the data sources used in the study will be covered in the methodology section. The analysis's conclusions and suggestions will be presented in the section under "Results and Discussion."

II. Literature Review

The literature review offers the basis for comprehending the overview of the generating firms (GenCos) in the electrical sector, as well as the theoretical and empirical frameworks that underlie the unequal effects of GenCo's natural gas consumption on the Nigerian economy. Using both global and regional viewpoints, this section reviews the literatures that dealt with the relationships among the growth of the economy, energy consumption (especially natural gas consumption), and NARDL models. The literature will also discuss how using natural gas has policy consequences and how it relates to economic outcomes and electricity generation.

Overview of Power Generation in Nigeria:

Nigeria electricity industry was unbundled in year 3013 and its ownership is predominantly private. Nevertheless, the transition is yet to deliver the anticipated outcomes. Following the enactment of the EPSRA (Electric Power Sector Reform Act) in 2004, the electricity industry was broken into six companies that generate electricity (GenCos), eleven companies to distribute (DisCos), and one Transmission Company (TCN) (World Bank, 2021). Figure 3 shows the Nigerian power sector, and its ownership after its unbundling.


Electricity grid

Sector unbundled into 6 Generation companies (GENCOs) Hydro (33 percent) and Gas (67 percent) based generation mix

State owned Transmission Company (TCN)

Government-owned Nigerian Bulk Electricity Trading Company (NBET) fulfills the role of bulk trader

11.8 million Grid customers in 2020. Distribution sector is privatized - includes 11 DISCOs divided geographically

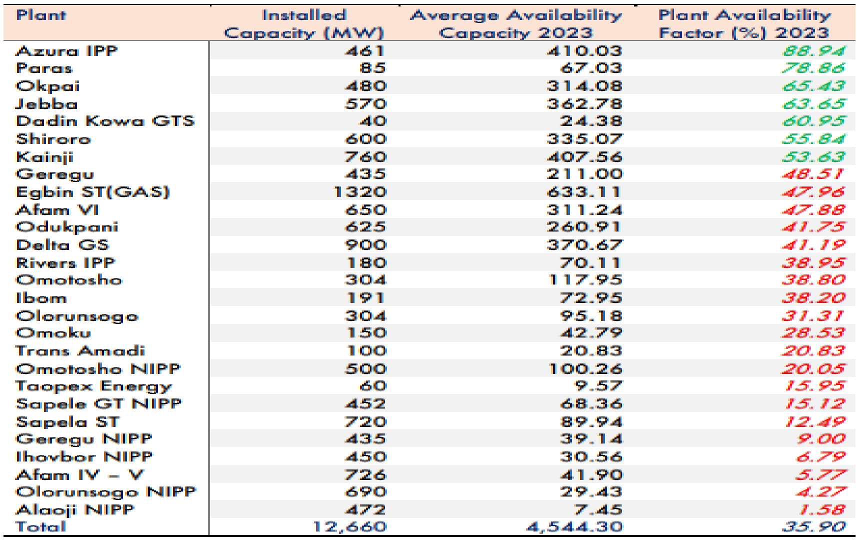
NBET buys electricity from GENCOs, including Independent Power Producers (IPPs), under Power Purchase Agreements (PPAs) and resells it to DISCOs under Vesting Contracts

Source: World Bank 2020.
Note: Thickness of the curved bars indicate volume of energy (GWh) flowing.

Figure 3: Nigeria's power sector, unbundled and privately owned. Source: World Bank: 2021

According to the 2023 report by the Nigerian Electricity Supply Industry (NESI), 27 grid-connected power plants are currently operational with capacity of all installed generators 12,660 MW, but the average available capacity stands at 4,544.30 MW, resulting in an overall plant availability factor of 35.90% as shown in Table 4.

Table 1: Plant Availability Factor (%) in 2023



Plant	Installed Capacity (MW)	Average Availability Capacity 2023	Plant Availability Factor (%) 2023
Azura IPP	461	410.03	88.94
Paras	85	67.03	78.86
Okpai	480	314.08	65.43
Jebba	570	362.78	63.65
Dadin Kowa GTS	40	24.38	60.95
Shiroro	600	335.07	55.84
Kainji	760	407.56	53.63
Geregu	435	211.00	48.51
Egbin ST(GAS)	1320	633.11	47.96
Afam VI	650	311.24	47.88
Odukpani	625	260.91	41.75
Delta GS	900	370.67	41.19
Rivers IPP	180	70.11	38.95
Omotosho	304	117.95	38.80
Ibom	191	72.95	38.20
Olorunsogo	304	95.18	31.31
Omoku	150	42.79	28.53
Trans Amadi	100	20.83	20.83
Omotosho NIPP	500	100.26	20.05
Taopex Energy	60	9.57	15.95
Sapele GT NIPP	452	68.36	15.12
Sapela ST	720	89.94	12.49
Geregu NIPP	435	39.14	9.00
Ihovbor NIPP	450	30.56	6.79
Afam IV – V	726	41.90	5.77
Olorunsogo NIPP	690	29.43	4.27
Alaoji NIPP	472	7.45	1.58
Total	12,660	4,544.30	35.90

In 2023, the national grid's gross generation was 36,710.38 GWh, averaging 4,190.68 MWh per hour as shown in Figure 4.

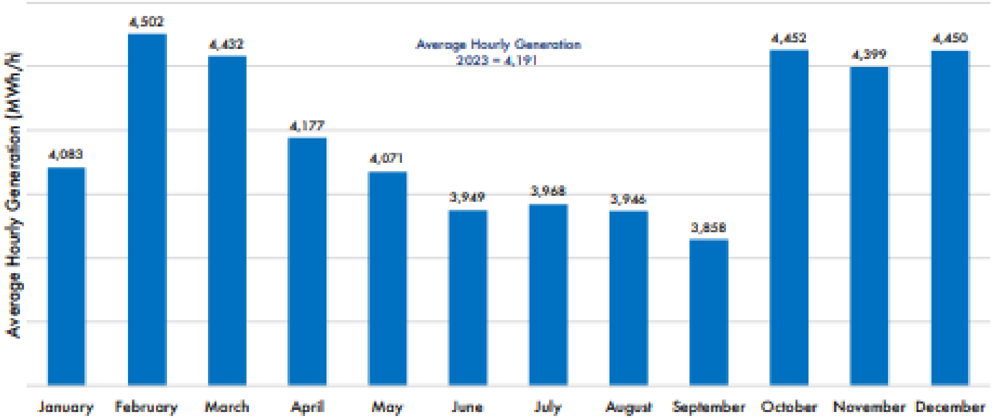


Figure 4: Average Hourly Generation (MWh per hour) in 2023. Source: NERC 2023

Most of the generation is thermal based (gas), with hydropower contributing 24.75% (9,086.90 GWh) to total generation. Mechanical outages were the primary cause of plant unavailability in 2023, affecting about 38.04% (4,802.80 MW) of total installed capacity. The aging infrastructure—where the average plant age in NESI was 21 years by December 2023—along with maintenance issues, were key factors in these outages. Additionally, liquidity challenges due to underpayment of invoices by distribution companies (DisCos) and unpaid government subsidies created financial constraints for generation companies (GenCos). Gas supply challenges also plagued thermal GenCos, arising from limited gas infrastructure and a lack of effective Gas Supply Agreements (GSA). The figure below shows the effect that the electricity sector finances from 2020 data from NERC.

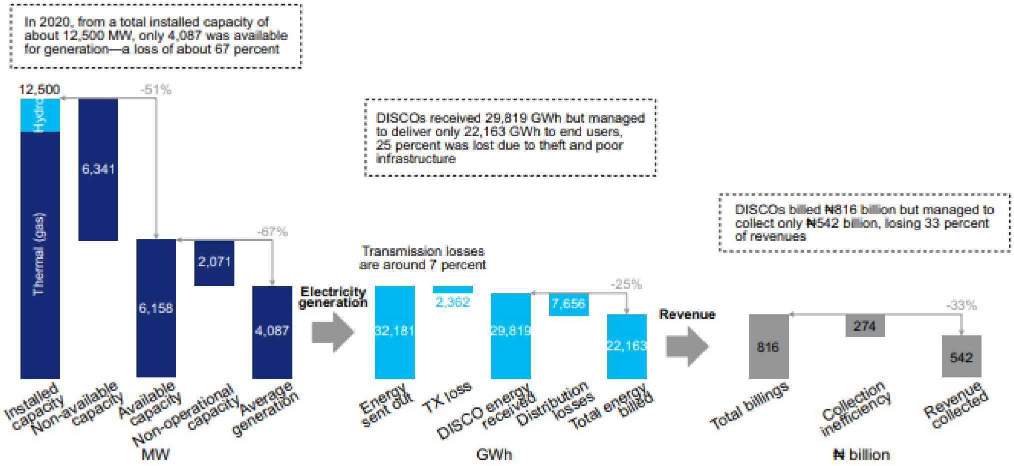


Figure 5: Financial Inefficiencies of Nigeria Electricity Sector. Source: World Bank, 2021

NERC, 2023, recommended that to resolve the challenges of GenCo's and improve their liquidity level, there is need to enforce prompt payment on DisCos and also timely payment of subsidy by the government. These actions would enable the GenCos meet their financial responsibilities in executing capital projects and other maintenance jobs to improve their capacity and plant reliability.

Theoretical Framework:

The following are some economic theories that are pertinent to this study to enable us comprehend the relationships existing between natural gas consumption by GENCOs and its impact on Nigeria's GDP:

Energy-Led Growth Hypothesis (ELGH):

This theory maintains that consumption of energy is a vital driver of the growth of the economy. Hence, energy serves as an input for production processes, enabling increased productivity and output across industries. The works of Apergis and Tang, 2013, Narayan and Prasad, 2008 and Ozturk, 2010 supports ELGH. Considering GenCos reliance on natural gas for power generation in Nigeria, it is expected to directly impacts industrial performance and, by extension, the GDP of the country.

Institutional Theory:

Institutions are indispensable in the development of energy policy and its utilization. The significance of regulatory frameworks, governance structures, and policy interventions in energy resource management is underscored by Institutional Theory. The performance of GenCos in Nigeria are significantly influenced by government policies regarding gas pricing, investment incentives and pipeline infrastructure. Inefficiencies in energy distribution and increased economic losses as a result of power theft and nonpayment of bills can be the result of weak institutional frameworks (North, 2012). In Nigeria, the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) is the regulator of the upstream sector of the petroleum sector while the downstream and midstream is regulated Nigerian Midstream Stream and Downstream Petroleum Regulatory Authority (NMDPRA). The Nigerian National Petroleum Company Limited (NNPC Ltd) became a commercial entity with government stake in the company in accordance with the Petroleum Industry Act (PIA, 2021). The International Oil Companies (IOCs) are major stakeholders in the upstream sector while Major Marketers and independent marketers are some of the major stakeholders in the downstream sector (PIA, 2021). The electricity industry is regulated by NERC (Nigerian Electricity Regulatory Commission)

Empirical Review:

This section will examine significant empirical studies that have analyzed the correlation between consumption of energy, specifically natural gas, and growth of the economy, concentrating on developing nations such as Nigeria.

Electricity Consumption and Economic Growth:

Numerous individuals have investigated the correlation between electricity or consumption of energy and the growth of the economy in both developing and developed nations. In Nigeria, natural gas consumption is a pivotal issue owing to its significance in power generation and industrial operations. Research by Oyeleke and Akinlo (2019) indicates that consumption of energy, encompassing gas, has a positive impact on GDP. Two-dimensional scatter plots featuring both linear and logarithmic regressions are used to show overarching trends and patterns, facilitating the identification and elucidation of the relationship between growth of the economy and gas-derived electricity generation in Nigeria. Figure 6 depicts the correlation between economic growth and gas-generated power, with the trend line demonstrating a positive relationship between the two throughout the study period.

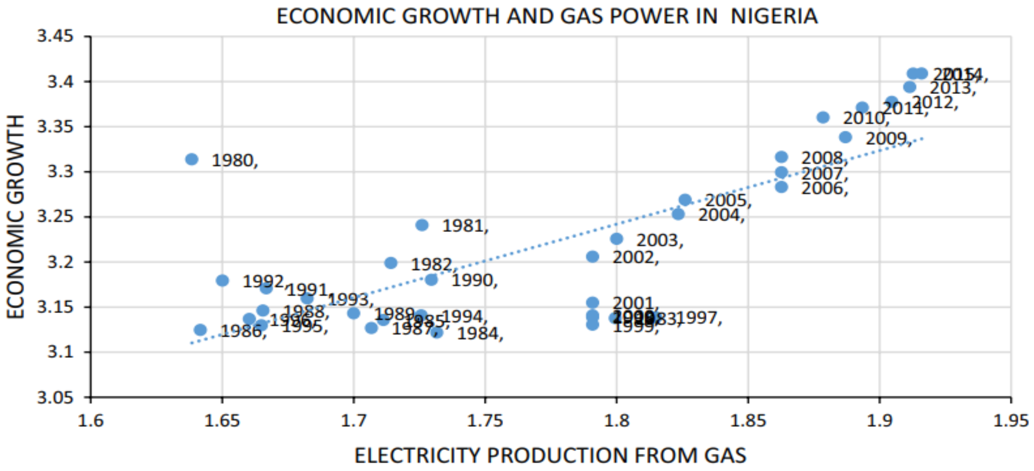


Figure 6: Economic growth and electricity production from gas in Nigeria.

Source: Oyeleke and Akinlo (2019) Fi

Shengfeng et al. (2012) used the Vector Error Correction Model (VECM) to analyze the short-term interaction and long-run connection between real GDP and consumption of energy in China from 1953 to 2009. The results indicated that the consumption of electricity and the country's real GDP are cointegrated, and that a unidirectional causal link exists between consumption of electricity and the growth of the economy in both the short and long run. The research recommended that China should enhance its efforts to reorganize its industrial framework and optimize its power supply system. The research was carried for China and not Nigeria.

Nazlioglu et al. (2014) examined the causative relationship between consumption of electricity and growth in the economy in Turkey from 1967 to 2007 using limits testing cointegration, non-linear Granger causality tests and linear Granger causality. Their findings proved the long-term cointegration of economic growth and electricity use. The error correction model indicated that the linear Granger causality findings demonstrated a two directional interrelationship between the variables were observed in the short term and long periods. Turkey was the area of interest in their research. On the other hand, Gokten and Karatepe (2016) revealed a unidirectional causal link between the growth of the economy and energy consumption using a bivariate Vector Autoregressive (VAR) causality test for the years 1950 to 2010.

Similar to this, Shahbaz (2015) used the OLS (Ordinary Least Squares) approach to investigate how Pakistan's sectoral GDP (agriculture, industry, and services) was affected by power outages between 1991 and 2013. The results showed that low levels of electricity have a detrimental effect on industrial sector production, have an inverse association with agricultural output, and exacerbate load-shedding in the service sector. The research suggested reducing needless energy use, encouraging the use of electricity-saving gadgets, and encouraging a better receptiveness to energy-saving strategies. The scope of the work is limited to Parkistan and the variables differ too.

Using cointegration and OLS techniques, Odedairo et al. (2013) investigated the link between energy consumption and the development of economy of Nigeria from 1975 to 2010. Their results showed a long-term association between the variables and showed that petrol use did not have a similar impact to that of petroleum and electricity consumption, which both had a substantial positive correlation with GDP. The result is agreement with that of this work, but the technique used is different.

Similarly, Azlina (2012) examined the correlation between Malaysia's GDP and energy use with a VECM. The research identified a causal association between GDP and consumption of energy, suggesting that economic expansion influences energy demand rather than vice versa.

Okorie and Manu (2016) assessed the causal relationship between Nigeria's economic progress and electricity consumption from 1980 to 2014, in comparison to Onyeisi et al. (2016). Utilizing VAR-based methodologies and Johansen cointegration, they successfully established a long-term relationship among the model's variables. The output indicated sustained link between the growth of the economy and utilization of energy. The causality study revealed a unidirectional causal link between energy use and growth in the country’s economy. They recommended that the government enhance daily energy output to meet the increasing demand. The method used is different although their recommendation is in line with the recommendation of this research paper.

Utilizing data from 1980 to 2011, Mustapha and Fagge (2015) reassessed the causal relationship between Nigeria's GDP and energy consumption via variance decomposition, impulse response, and causality analyses. The causality test revealed no causal relationship between the variables. Moreover, a variance decomposition analysis indicates that labour and capital have a more substantial impact on output growth than energy use. The variables of this work are different from those of this work, hence, the gaps need to be filled. Most of these researches concentrated on the linear connection, and ignored the possibility of asymmetric effects due to variations in the energy supply.

Asymmetric Effects of Energy Consumption using the NARDL model:

Since its introduction by Shin et al. (2013), the NARDL (Nonlinear Autoregressive Distributed Lag) model has gained popularity as a useful tool for analysing asymmetric interactions in economic research. This approach enables researchers to discriminate between changes in an independent variable (natural gas consumption by GenCos in this example) that are positive or negative in relation to a dependent variable (GDP). The NARDL model is used in a number of recent research that examined the asymmetric impacts of energy consumption and how variations in energy use impact the economy. When Shin et al. (2013) used the NARDL technique to investigate the asymmetric impacts of oil consumption on economic development in South Korea, they discovered that the negative consequences of declining oil supply outweighed the benefits of rising supply. Using data from 1990 to 2014, Farhani and Rahman (2020) researched on the natural gas usage versus economic development in France. To ascertain the long-term link between the variables, they used ARDL testing technique. In order to determine the direction of causation, they also used the Granger causality approach, which is a VEC model. Their results demonstrated a long-run cointegration among the variables, with labour, capital, exports, and natural gas consumption all contributing to France's economic expansion. The findings of the causality analysis validated the energy-led growth theory, indicating that economic expansion is driven by petrol consumption. The area of concern to the authors were France although the result is supported by this research paper.

Galadima and Aminu (2018) employed the smooth transition regression (STR) technique to investigate Nigeria’s economic growth versus the utilization of natural gas from 1981 to 2015. The results of this research demonstrated that there is an asymmetry link connecting natural gas utilization and the economic advancement in Nigeria. The threshold for natural gas usage in the nation was 9,085.36 standard cubic meters, but where consumption was below the optimum level. Additionally, it was discovered that natural gas utilization, in both low and high regimes, had a favourable and significant effect on Nigeria GDP. There is a variation in the variables and scope of their work from that of this paper.

Galadima and Aminu (2019a) analysed the shock effects of macroeconomic variables on Nigeria's natural gas consumption. They used a structural VAR (SVAR) model with sign limitations to evaluate how shocks from macroeconomic variables, including: money supply, inflation, real GDP, and exchange rate were transmitted onto the use of natural gas. The findings showed that natural gas consumption responded considerably to shocks originating from the money supply and real GDP in the long run and further in short run, but only in the short-term and not significantly in the case of inflation shock. In ordering the variance decomposition, however, the money supply, real GDP, inflation, and exchange rate have all contributed to shocks to a greater extent. 35 observations from annual time for the years 1981 to 2015 were used in this investigation. The scope as well as the variables and techniques are different from those of this research paper.

Ekeocha, Penzin, and Ogbuabor (2020) used several model parameters to reassess the interaction of Nigeria’s economic growth and her energy consumption from 1999 to 2016. This experiment used a nonlinear (or asymmetric) ARDL model, alongside an ARDL-ECM framework that posits a linear correlation rather than a nonlinear one. Their analysis revealed that the impact of energy use on growth was negligible. Granger causality tests demonstrated a unidirectional causal link between economic development and energy use. This research examined the period from 1999 to 2016. The scope and the variables of their research vary from those of this paper.

Yakubu et al. in 2022 investigated the influence of electrical power on Nigeria's economic development from 1981 to 2019. The ARDL bounds cointegration test was used after they verified the order of integration among the variables (mixed order), as established by the ADF and PP tests. The findings indicate that electricity consumption has a statistically significant and positive influence on the growth of the economy for the short and long run. Henry et al. (2021) worked on the impact of transmission and distribution losses, representing electric power shortages, on Nigeria's economic development, focusing on the real GDP of the industrial and agricultural sectors. They found that a 1% rise in electric power transmission and distribution losses leads in a 3% long-term decline in agricultural production, whereas the short-term impact is minimal. This analysis utilized data span from 1981 to 2017 and they used ARDL model. The variables and scope of their work is quite different from those of this paper.

Research Gaps and Contributions:

There are significant gaps in the literature, particularly when it comes to the asymmetric impacts of GenCos natural gas use and the growth of Nigerian economy. Nevertheless, the body of current research offers a strong foundation for understanding the relationship between them. The predominant body of research has concentrated on linear relationships, neglecting the potential for varying impacts on economic output resulting from fluctuations in energy use. Moreover, despite its use in several economic studies, the NARDL methodology has not been thoroughly investigated regarding this topic. This study aims to address these gaps by:

1. analyzing the asymmetric impacts of natural gas consumption by Nigerian electric power plants on GDP;
2. utilizing the NARDL method to effectively capture the diverse implications of variations in natural gas consumption; and
3. offering policy recommendations based on the research findings to optimize the use of natural gas for power generation and economic advancement in Nigeria.

III. Methodology

In this research study, the impact of natural gas usage on the Nigerian economy was assessed using NARDL model. The NARDL method was used to examine quarterly data on the consumption of natural gas in power plants and its asymmetric effects on GDP. Other variables considered include LPG consumption and Natural gas consumption by industries. The study utilized data from an 11-year period to explore the implications and validity of the long-term connections between the growth of the economy and domestic gas consumption of power plants.

Introduction to NARDL

The NARDL model is a technique that aims to evaluate the long-term association among variables and consider non-linearity and short-term dynamics. It is a variation of the linear ARDL model, which includes non-linear terms such as polynomials and logarithms in the equations (Pesaran, 2017). The ARDL model evaluates the correlation among variables over both short-term and long-term periods by incorporating both autoregressive and distributed lag components. The autoregressive component examines the short-term dynamics of the relationship, including the potential for feedback effects among the variables. Meanwhile, the distributed lag component analyzes the long-term dynamics, including the potential for equilibrium relationships among the variables over the long-term. The steps taken to carry out NARDL analysis starts with identifying the variables of interest. Next is to do stationary tests to ensure that the data is suitable for the analysis. If the variables are stationary at level and first difference, then bounds test follows to ascertain for cointegration. The NARDL test is then done followed by diagnostics and stability tests.

Research Design:

Quantitative research approach would be used, which is especially adept at examining the correlation between use of natural gas by GenCos) and Nigeria's GDP. The research utilizes a quantitative methodology, applying statistical and econometric approaches to evaluate the hypothesis and elucidate the link between the variables. The study used the NARDL model to detect possible asymmetries among the variables.

Data Collection and Sources:

The research relied on secondary data sourced from credible references to guarantee precision and dependability. This study examined quarterly data spanning from Q1 2010 to Q4 2020, offering a comprehensive perspective on the long-term correlation between consumption of natural gas by GenCos and Nigeria's GDP. This period includes critical occurrences that have impacted GDP, notably the COVID-19 pandemic. The study investigation used data for 11-year period to assess the relationship between power plants gas consumption versus economic growth, while also identifying potential causal links. The quarterly data yields 44 data points, facilitating a comprehensive examination of economic performance over time, emphasizing long-term trends, and providing enhanced reliability compared to shorter-term data by reducing noise. This renders it especially advantageous for policy making and the formulation of business decisions.

Table 2: Description of variables

Variable	**Abbreviation**	**Unit**	**Publisher**
Real Gross Domestic Product	GDP	Billion Naira	Central Bank of Nigeria
LPG Consumption	GH	Metric Tons	United Nations data
Gas consumption for electric power generation	GE	Billion Cubic Meters	Gas Exporting Countries Forum
Gas consumption by industries	GI	Billion Cubic Meters	Gas Exporting Countries Forum

Model Specification and Description

The research employs the NARDL technique, as established by Shin et al. (2013), to examine the asymmetric impacts of consumption of natural gas by GenCos on Nigerias GDP. Its primary benefit is its capacity to differentiate between the effects of fluctuations in the independent variable (GenCos - GE) on the dependent variable (GDP).

The linear relationship is expressed as follows: the linear functional form can be represented as:

$$GDP = f(GH, GE, GI) \quad (3.1)$$

The equation stated represents the specified model. It can also be expressed in a non-linear functional form where the explanatory variables are split into positive and negative partial forms:

$$GDP = f(GH^{+}, GH^{-}, GE^{+}, GE^{-}, GI^{+}, GI^{-}) \quad (3.2)$$

expressed in form of coefficients as;

$$GDP = \alpha_0 + \alpha_1 GH^{+} + \alpha_2 GH^{-} + \alpha_3 GE^{+} + \alpha_4 GE^{-} + \alpha_5 GI^{+} + \alpha_6 GI^{-} + \epsilon_t \quad (3.3)$$

The functional models at equation 3.3 is best expressed by taking the logarithm transform of each variable. This is to ensure that the units of each variable are consistent, and this helps in addressing the non-stationarity of data.

Taking log of both side in equation 3.3

$$LGDP = \alpha_0 + \alpha_1 LGH^{+} + \alpha_2 LGH^{-} + \alpha_3 LGE^{+} + \alpha_4 LGE^{-} + \alpha_5 LGI^{+} + \alpha_6 LGI^{-} + \epsilon_t \quad (3.4)$$

Where:

LGDP = Natural Logarithm of Real GDP

LGH = Natural Logarithm of LPG consumption

LGE = Natural Logarithm of Gas consumption for electric power generation

LGI = Natural Logarithm of Gas consumption for industries

α_0 = Intercept

$\alpha_{1,}\ \alpha_{2\ldots}\ \alpha_6$ are the parameter estimates for the dependent variables

ϵt = Error term

Estimation Technique (NARDL)

The developed model is articulated as double-logged model. A double log model serves as a robust econometric method for examining the relationship among dependent and independent variables by transforming them into natural logarithms. Pesaran and Shin (1999). The cointegration test applied with this model is the NARDL bounds test, which allows the evaluation of both long-term and short-term dynamics, as noted by Narayan and Poi (2005). Other benefits of this method when compared to other methods include: (i) Its capacity to show how the variables react to positive and negative changes among the variables and the changes in these responses with time variation. (ii) it has the capacity to carry out short- and long run estimates of regressors with respect to regressand. These benefits and more led to the choice of this technique.

Steps in conducting NARDL analysis

To ensure the accuracy and reliability of the NARDL model, several tests must be conducted. Firstly, the stationarity of the variables must be tested using the ADF, KPSS tests or any other unit root test, as the ARDL model only works with I(0) and/or I(1) variables (Emeka and Aham, 2016, Udoudo et al., 2023). Once stationarity is confirmed, the optimal lag for the ARDL model must be determined using different criteria (AIC criteria was used) to account for any biases. The NARDL model can then be built from the ARDL model, and cointegration tests is conducted to determine the presence of a long-run relationship between the dependent and explanatory variables. The short-run and long-run coefficients can be generated, taking the error correction term into account. Wald tests can then be used to confirm the long- and short-run asymmetries. To validate the results, tests for autocorrelation, normality and heteroscedasticity must be conducted. Stability tests must also be performed to ensure that the estimated coefficients are reliable, confirming the robustness of the model (Sohail et al., 2021). For this purpose, we considered the Cumulative sum and Cumulative Sum of Squares to examine stability and reliability of the models.

Finally, the outcomes should be analyzed to see if they make intuitive sense.

The generalized asymmetry or nonlinear equation is expressed as:

$$Y_t = f(Y_{t-1}, X_{t-1}, \varepsilon_t) + \varepsilon_t \quad (3.5)$$

When using the non-linear ARDL to analyze Y and X, the equation would be represented as:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \beta_1 Y_{t-1} X_{t-1} + \gamma_1 (Y_{t-1})^2 + \delta_1 (X_{t-1})^2 + \varepsilon_t \quad (3.6)$$

Where α_1, α_2, β_1, γ_1 and δ_1 are parameters and ε_t error term.

X_t can be further decompose as:

$$X_t = X_o + X_t^+ + X_t^- \quad (3.7)$$

$$X_t^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} (\Delta x_i, 0) \quad (3.8)$$

$$X_t^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} (\Delta x_i, 0) \quad (3.9)$$

The decomposed equations are substituted into an ARDL setting suggested by Pesaran et al. (2001):

$$\Delta Y_t = \rho Y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{i-1}^{p-1} \varphi_i \Delta y_{t-i} + \sum_{i=0}^{q} (\pi_i^+ \Delta x_{t-i}^+ + \pi_i^- \Delta x_{t-i}^-) + \epsilon_t \quad (3.10)$$

where,

Y_t = dependent part, and

X_t =independent part

X_t^+ and X_t^- are partial sum of X_t

$\beta^+ = \frac{\theta^+}{\rho}$, and $\beta^- = \frac{\theta^-}{\rho}$ associated parameters to X_t on Y_t.

This is calculated by dividing both

$\sum_{i=0}^{q} (\pi_i^+)$ and $\sum_{i=0}^{q} (\pi_i^-)$ are estimates of the increase and reduction of the short-run impacts of the independent variables.

Null hypothesis or no co-integration, is expressed as:

$$\Delta LGDP_t = \beta_{01} + \sum_{i=1}^{q_0} \beta_{1i} LGDP_{t-i} + \sum_{i=0}^{q_1} \beta_{2i} LGH_{t-i} + \sum_{i=0}^{q_2} \beta_{3i} LGE_{t-i} + \sum_{i=0}^{q_3} \beta_{4i} LGI_{t-i} \quad (3.11)$$

Here, q at 0,1,2,3,4 denotes the maximum lags for LGDP, LGH, LGE, and LGI, respectively.

Thus, for co-integration to exist, an error correction model (ECM) representation is generated as:

$$\Delta LGDP_t = \beta_{01} + \sum_{i=1}^{q_0} \beta_{1i} LGDP_{t-i} + \sum_{i=0}^{q_1} \beta_{2i} LGH_{t-i} + \sum_{i=0}^{q_2} \beta_{3i} LGE_{t-i} + \sum_{i=0}^{q_3} \beta_{4i} LGI_{t-i} + \lambda ECT_{t-1} + \epsilon_t \quad (3.12)$$

$$\begin{aligned}\Delta LGDP_t = \beta_{01} &+ \sum_{i=1}^{q_1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{q_2} \beta_{2i}^+ \Delta LGH_{t-i}^+ + \sum_{i=0}^{q_3} \beta_{3i}^- \Delta LGH_{t-i}^- + \sum_{i=0}^{q_4} \beta_{4i}^+ \Delta LGE_{t-i}^+ \\ &+ \sum_{i=0}^{q_5} \beta_{5i}^- \Delta LGE_{t-i}^- + \sum_{i=0}^{q_6} \beta_{6i}^+ \Delta LGI_{t-i}^+ + \sum_{i=0}^{q_7} \beta_{7i}^- \Delta LGI_{t-i}^- + +\beta_8{}^+ LGH_{t-1}^+ + \beta_9{}^- LGH_{t-1}^- \\ &+ \beta_{10}^- LGE_{t-1}^+ + \beta_{11}^- LGE_{t-1}^- + \beta_{12}^- LGI_{t-1}^+ + \beta_{13}^- LGI_{t-1}^- + \rho LGDP_{t-1} \\ &+ \epsilon_t \quad (3.13)\end{aligned}$$

The estimation of the non-linear ECM in the short-run to evaluate the asymmetric effect among the variables is derived from equation 3.13 as:

$$\Delta LGDP_t = \beta_{01} + \sum_{i=1}^{q_1} \beta_{1i}\Delta LGDP_{t-i} + \sum_{i=0}^{q_2} \beta_{2i}^{+} \Delta LGH_{t-i}^{+} + \sum_{i=0}^{q_3} \beta_{3i}^{-} \Delta LGH_{t-i}^{-} + \sum_{i=0}^{q_4} \beta_{4i}^{+} \Delta LGE_{t-i}^{+} + \sum_{i=0}^{q_5} \beta_{5i}^{-} \Delta LGE_{t-i}^{-} + \sum_{i=0}^{q_6} \beta_{6i}^{+} \Delta LGI_{t-i}^{+} + \sum_{i=0}^{q_7} \beta_{7i}^{-} \Delta LGI_{t-i}^{-} + +\beta_8{}^{+} LGH_{t-1}^{+} + \beta_9{}^{-} LGH_{t-1}^{-} + \beta_{10}{}^{+} LGE_{t-1}^{+} + \beta_{11}{}^{-} LGE_{t-1}^{-} + \beta_{12}{}^{+} LGI_{t-1}^{+} + \beta_{13}{}^{-} LGI_{t-1}^{-} + \rho LGDP_{t-1} + ECT + \epsilon_t (3.14).$$

Where,

- Real GDP, LPG consumption (GH), Electric power plant gas consumption (GE), and Industry gas consumption (GI) are variables expressed in logarithm.
- ϵ_t = Error term
- ECT = Error correction term.
- q = best lag order in relation to the variable
- β_{1i} to β_{7i}, and α_1 toα_{i3} represents the asymmetric coefficients of the short-run.
- β_8 to β_{13} and α_4 to α_5 represents the asymmetric coefficients.
- ρ represents the long-run coefficient of the dependent term.

$\beta^+ = \frac{\beta_i{}^+}{\rho}$, and $\beta^- = \frac{\beta_i{}^-}{\rho}$ (3.15)

Assuming, $\beta_i{}^+$ and $\beta_i{}^-$represents the positive and negative asymmetric coefficients of the independent variable, respectively and, ρ represents the long-run coefficient of the dependent variable.

Wald Test is then applied to confirm the presence of long-term and short-run asymmetries in NARDL modeling, the Wald Test is employed (Shin, Yu, & Greenwood-Nimmo, 2014). The test is based on a comparison of the sums of square residuals between the restricted and unrestricted models, resulting in a test statistic. If the calculated test statistic is higher than the critical value of the Chi-square distribution, the null hypothesis is rejected, indicating that significant asymmetry exists. The null hypothesis assumes that the coefficients are equal, indicating no long-term asymmetry, while the alternative hypothesis indicates the presence of long-run asymmetry by indicating that the coefficients are not equal.

The test statistic is calculated as:

$$WLR = [g(\gamma) - g(-\gamma)]' \, [Var[g(\gamma) - g(-\gamma)]]^{-1} \, [g(\gamma) - g(-\gamma)] \quad (3.16)$$

Where, γ is the estimated coefficient of the ECM term, $g(\gamma)$ is the vector of restrictions on the coefficients, and $Var[g(\gamma) - g(-\gamma)]$ is the covariance matrix of the limits.

The asymmetric dynamic multiplier equations: The dynamic multipliers describe the process by which the dependent variable (LGDP) adapts to a new long-term equilibrium following the consequences of positive and negative shocks from the independent variables.

$$m^{+}{}_{q} = \sum_{i=0}^{q_i} \frac{\Delta Y_{t+i}}{\Delta X_t}, \quad m^{-}{}_{q} = \sum_{i=0}^{q_i} \frac{\Delta Y_{t+i}}{\Delta X_t} \quad (3.17)$$

$m^{+}{}_{q} = \sum_{i=0}^{q_i} \frac{\Delta Y_{t+i}}{\Delta X_t}$, Where, as q → ∞, $m^{+}{}_{q} \rightarrow \frac{\beta_i{}^+}{\rho}$, and $m^{-}{}_{q} \rightarrow \frac{\beta_i{}^-}{\rho}$ and m is the asymmetric multiplier.

IV. Results and Discussion:

The NARDL model results is hereby presented and discussed.

Unit Root Tests:

The ADF test result reported in Tables 3 shows that the LGDP was seen to be stationary at level zero while LGE and LGH were found to be stationary at order one and LGI maintained stationarity at both levels. According to Udoudo et al., 2023, Engel-Granger and Johansen co integration method is not suitable for the analysis because of the distinct order in the stationary of the variables. The results validate the use of the NARDL method in conducting co-integration test among the variables.

Table 3: ADF Unit Root Test result

	Level I(0)		**First difference I(1)**		
Variable	**Test value**	**Probability**	**Test value**	**Probability**	**Stationarity**
LGDP	ADF (-4.749873)	**0.004**	ADF (-1.877482)	**0.3391**	**I (0)**
	1% (-3.605593)		1% (-3.610453)		
	5%(-2.936942)		5% (-2.938987)		
	10%(-2.606857)		10% (-2.607932)		
LGE	ADF (-1.464311)	**0.5408**	ADF (-5.209183)	**0.0001**	**I (1)**
	1% (-3.610453)		1% (-3.610453)		
	5% (-2.938987)		5% (-2.938987		
	10% (-2.607932)		10% (-2.607932)		
LGH	ADF (-0.142578)	**0.9374**	ADF (-6.155365)	**0.0000**	**I (1)**
	1% (-3.610453)		1% (-3.610453)		
	5% (-2.938987)		5% (-2.938987)		
	10% (-2.607932)		10% (-2.607932)		
LGI	ADF (-3.289609)	**0.0216**	ADF (-6.521649)	**0.0000**	**I (0) & I (1))**
	1% (-3.592462)		1% (-3.596616)		
	5% (-2.931404)		5% (-2.933158)		
	10% (-2.603944)		10% (-2.604867)		

Source: Author's Compilation from EVIEWS

NARDL Estimation:

Table 4: NARDL Estimation Output for the Model

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
LGDP(-1)	-0.854321	0.307486	-2.778407	0.0141
LGDP(-2)	-1.185284	0.177767	-6.667629	0.0000
LGDP(-3)	-0.843448	0.298923	-2.821627	0.0129
LGE_POS	0.040427	0.083637	0.483367	0.6358
LGE_NEG	0.064744	0.102232	0.633306	0.5361
LGE_NEG(-1)	0.088743	0.135408	0.655378	0.5221
LGE_NEG(-2)	0.218898	0.131488	1.664777	0.1167
LGE_NEG(-3)	0.237984	0.140494	1.693908	0.1109
LGH_POS	0.058336	0.140547	0.415066	0.6840
LGH_POS(-1)	0.235205	0.125952	1.867415	0.0815
LGH_POS(-2)	0.071230	0.137125	0.519452	0.6110
LGH_POS(-3)	0.281587	0.117546	2.395552	0.0301
LGH_NEG	-0.486404	0.492703	-0.987214	0.3392
LGH_NEG(-1)	-0.955528	0.449937	-2.123692	0.0507
LGH_NEG(-2)	-0.393322	0.497657	-0.790348	0.4416
LGH_NEG(-3)	-1.282468	0.431013	-2.975476	0.0094
LGI_POS	0.289799	0.106718	2.715562	0.0160

LGI_POS(-1)	-0.177491	0.124046	-1.430844	0.1730
LGI_POS(-2)	-0.066860	0.131556	-0.508227	0.6187
LGI_POS(-3)	-0.231602	0.111227	-2.082240	0.0549
LGI_NEG	-0.214615	0.162028	-1.324560	0.2051
LGI_NEG(-1)	0.385519	0.188653	2.043538	0.0590
LGI_NEG(-2)	0.352028	0.209302	1.681912	0.1133
LGI_NEG(-3)	0.248092	0.193504	1.282102	0.2193
C	36.68142	6.475460	5.664682	0.0000
R-squared	0.974034	Mean dependent var		9.724505
Adjusted R-squared	0.932488	S.D. dependent var		0.095240
S.E. of regression	0.024746	AIC		-4.291119
Sum squared resid	0.009186	Schwarz criterion		-3.235569
Log likelihood	110.8224	Hannan-Quinn criter.		-3.909466
F-statistic	23.44482	Durbin-Watson stat		1.996801
Prob (F-statistic)	0.000000			

Source: Authors Compilation from Eviews

The results in Table 4 displayed the regression of the model. The value of Durbin-Watson stat of 1.9968, F-statistic of 23.4448, R-squared of 0.9740 and adjusted R squared of 0.9324 is positive indication to the quality of the model.

The Bound test:

According to Emeka and Aham, 2016, when the calculated F statistics value is higher than the upper bound I(1) of critical values, then we confirm the presence of co-integration among the variables. Secondly, when the calculated value of F statistics is smaller than the lower bound I(0) of the critical values, it means that no co-integration exists among the variables. Thirdly, where the calculated F statistics value lies between the lower bound I(0) and upper bound I(1), the test is assumed inconclusive. In Table 5, the F-statistic for the model is 7.083805. This value is compared against the I(0) and I(1) (lower and upper bounds respectively) at significant levels of 1%, 5%, and 10%. The results demonstrate that the F-statistic exceeds both bounds at all levels, hence, null hypothesis (H_0) of no cointegration is therefore rejected. This suggests the presence of asymmetric cointegration among the variables, underscoring the role of asymmetries and nonlinearities in analyzing Nigeria's GDP. The result of the F-bound test displayed in Table 5 with F statistics value of 7.0838 which is far greater than the value of the upper bound critical value of 3.61 at 5% significance shows that we can proceed to carry out long run and short run estimation of the model (Sohail et al., 2021).

Table 5: F-bound co-integration results

TEST STAT	**Value**	**Significant**	**I(0) Asymptotic: n=1000**	**I(1) Asymptotic: n=1000**
F- statistics	7.083805	10%	2.12	3.23
K	6	5%	2.45	3.61
		2.5%	2.75	3.99
		1%	3.15	4.43

Source: Author’s Compilation from EVIEWS

The Long run estimation

Table 6: Long-run Estimations for the specified NARDL model

	Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
MODEL	**LGE_POS**	0.010411	0.020596	0.505492	0.0206
	LGE_NEG	0.157188	0.022772	6.902544	0.0000
	LGH_POS	0.166456	0.017231	9.660322	0.0000

	LGH_NEG	-0.802905	0.071167	-11.28201	0.1200
	LGI_POS	-0.047940	0.023763	-2.017394	0.0619
	LGI_NEG	0.198561	0.034754	5.713354	0.0000

The long-run coefficients are 0.010411, and 0.157188, respectively, with a probability value of 0.0206, and 0.000 respectively. This implies that for every 1% increase in LGE in positive direction, the LGDP increases by **1.04%,** in the long-run. Moreso, the LPG consumption (LGH) in the positive, and negative direction had a positive, and negative impact on LGDP, respectively. The long-run coefficients are 0.166456, and -0.802905, respectively, with a probability value of 0.000, and 0.1200 respectively. This implies the impact of LGH in positive direction is statistically significant but insignificant in the negative direction, i.e for every 1% rise in LGH in positive direction, the LGDP increases by **16.64%**. There is no effect on the negative direction of LPG consumption on GDP because it is not statistically significant.

Furthermore, the gas consumption in Industries (LGI) have significant impacts on LGDP in the negative direction but insignificant in the positive direction (LGI_POS, and LGI_NEG). The long-run coefficients are -0.047940, and 0.198561, respectively, with a probability value of 0.0619, and 0.000, respectively. This implies the impact of LGI in positive direction is statistically insignificant, but significant in the negative direction at a 5% probability threshold. This means that for every 1% drop in industries gas consumption, the GDP decreases by **19.85%**.

The asymmetric cointegrating level equation for the model can be represented as:

$$\Delta LGDP_t = 0.010411LGE_t^+ + 0.157188LGE_t^- + 0.166456LGH_t^+ - 0.802905LGH_{t-1}^- - 0.047940LGI_t^+ + 0.198561LGI_t^- \quad \textbf{(4.1)}$$

The model can be used to predict the estimates for the parsimonious NARDL equation at different lag periods.

Table 7: Short-Run Estimations for the Specified NARDL Model

	Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
MODEL	C	36.68142	4.398251	8.340001	0.0000
	D(LGDP(-1))	2.028732	0.253667	7.997624	0.0000
	D(LGDP(-2))	0.843448	0.197796	4.264237	0.0007
	D(LGE_NEG)	0.064744	0.077558	0.834782	0.4169
	D(LGE_NEG(-1))	-0.456882	0.096083	-4.755051	0.0003
	D(LGE_NEG(-2))	-0.237984	0.090506	-2.629491	0.0190
	D(LGH_POS)	0.058336	0.091121	0.640206	0.5317
	D(LGH_POS(-1))	-0.352817	0.100490	-3.510971	0.0032
	D(LGH_POS(-2))	-0.281587	0.083726	-3.363218	0.0043
	D(LGH_NEG)	-0.486404	0.335591	-1.449394	0.1678
	D(LGH_NEG(-1))	1.675790	0.389395	4.303573	0.0006
	D(LGH_NEG(-2))	1.282468	0.309275	4.146684	0.0009
	D(LGI_POS)	0.289799	0.070417	4.115445	0.0009
	D(LGI_POS(-1))	0.298462	0.092527	3.225682	0.0057
	D(LGI_POS(-2))	0.231602	0.079656	2.907528	0.0108
	D(LGI_NEG)	-0.214615	0.120714	-1.777878	0.0957
	D(LGI_NEG(-1))	-0.600120	0.151935	-3.949861	0.0013
	D(LGI_NEG(-2))	-0.248092	0.117290	-2.115203	0.0516
	CointEq(-1)*	-3.883053	0.466044	-8.331944	0.0000
	R-squared	0.967810	Mean dependent var		0.006847

	Adjusted R-squared	0.940219	S.D. dependent var	0.085539
	S.E. of regression	0.020914	Akaike info criterion	-4.591119
	Sum squared resid	0.009186	Schwarz criterion	-3.788901
	Log likelihood	110.8224	Hannan-Quinn criter.	-4.301063
	F-statistic	35.07658	Durbin-Watson stat	1.996801
	Prob(F-statistic)	0.000000		

Source: Author's Compilation from EVIEWS

From the estimates, the model shows that the gas consumption by GenCos in the negative direction D(LGE_NEG) has a positive impact on LGDP in the short run. The short-run coefficient for D(LGE_NEG) is 0. 064744 and its respective probability value is 0. 4169. This indicates that the impact of D(LGE_NEG) in the current period is statistically insignificant. This also means that for every 1% decrease in (D(LGE_NEG)) during the current period, the LGDP decreases by 45.68%. %. Additionally, the coefficient of the co-integration equation during the previous year (CointEq(-1)) denotes the Error Correction Mechanism (ECM). The model generates a negative and statistically significant coefficient of the ECM at -3.883053. It indicates that approximately **388%** of the short-run disequilibrium from the previous year's disturbance converges back to a long-run equilibrium in the present year. The adjusted R-Square revealed that 94.02% variation in the LGDP is explained by the changes in logged value of gas consumption in industries, electric plants, and LPG consumption. The F-statistic value of **35.07658 and p-value of 0.0000** proves the relevance and adequacy of the NARDL model.

The ECM equation for short run can be expressed as:

$$\Delta LGDP_t = -3.883053ECT_{t-1} + 2.028732LGDP_{t-1} + -0.456882LGE_t^- - -0.352817LGH_{t-1}^+ + 1.675790LGH_{t-1}^- - 0.600120LGC_{t-1}^- + 36.68142 \qquad (4.3)$$

Wald Tests for the Long-run and Short-run asymmetries.

Tables 8 present the results of the Wald test, which examines the existence of both long-run and short-run asymmetries. At a 0.05 significance level, the results reveal that the effect of LGE on LGDP is asymmetric in the long run, as indicated by the Chi-square probability of 0.0072. This leads to the rejection of the null hypothesis, suggesting asymmetries in the long term. In the short term however, the probability value of 0.0590 confirm symmetry.

Table 8: Wald Tests

Variable	Analysis	Test stat	Value	df	Prob	Inference
LGE	Long run	T-stat	-2.862723	33	0.0072	Asymmetric
		F-stat	8.195183	1, 33	0.0072	
		Chi- square	8.195183	1	0.0042	
	Short run	T-stat	-1.951442	35	0.0590	Symmetric
		F-stat	3.808125	1, 35	0.0590	

Source: Author's Compilation

NARDL Dynamic Multipliers

To analyze how variables impact GDP over time, dynamic multipliers are used to track their effects, particularly identifying any asymmetries caused by changes in independent variables. A positive change in the dependent variable follows the solid black line, while a negative shock follows the dotted black line. The light-dotted red line shows the asymmetric plot, with upper and lower bands, and the dark red dotted line indicates the difference between positive and negative changes. If the x-axis zero line falls within this interval, it indicates no asymmetric effect from the explanatory variable.

Figure 9 shows that electric power plants (GE) gas consumption impact on GDP is asymmetric in the long run, aligning with the results of the long run Wald tests. The value of the negative shock at long run is about (-7) while the positive shock stood below (6) as represented by the tiny, dotted lines, the upper one for positive and the lower for negative response of GDP to gas consumption by power plants. This is in agreement with the result of the Wald test that confirmed asymmetry in long run. The effect of negative shock is higher in agreement to the NARDL output where the negative effect of gas consumption had higher effect on the Nigerian GDP. In figure 9 legend, the black solid line represents positive while the black dotted line represents negative shocks, we see that at the short run, there is symmetry between the positive shocks and negative shocks as the asymmetric plot lie along the zero line and around the 95% significance. This graph support the result of the Wald test that affirmed symmetry in the short term. The thick red dotted line is the asymmetric plot and in the long run, it tilted towards the negative part of the graph thereby supporting the NARDL output of higher negative impact in the long run and Wald test asymmetric result in the long run.

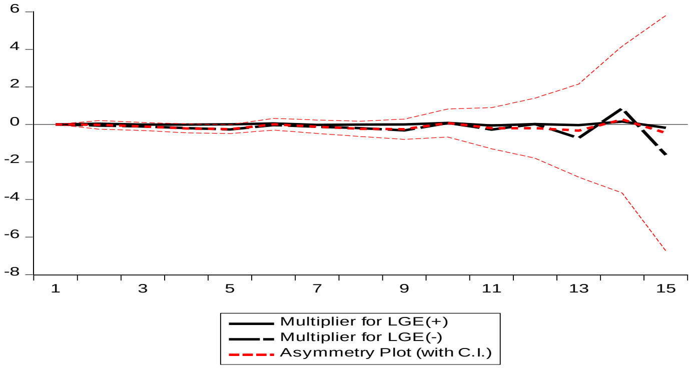


Figure 9: LGE Multiplier

Diagnostic Tests

Diagnostic tests were further carried out to confirm the robustness of the model such as normality of residuals, heteroskedasticity, Ramsey Reset and serial correlation tests. The results indicate that the model lack autocorrelation issues because the estimated LM statistic is statistically insignificant, the result of the Ramsey RESET test statistic confirms that the model is well-specified. Furthermore, the output from the ARCH tests confirmed that there are no heteroscedasticity issues with the model. Finally, the normality test with Jaque-Bera of 2.8184 and probability value of 0.244 confirms that the residual series are normally distributed. The results of these tests are summarized in the Table 9.

Table 9: Diagnostic Tests

TEST	STATISTICS			
Breusch-Godfrey Serial Correlation LM Test	F-STAT	0.180544	Prob. F(2,13)	0.8369
	Obs*R-squared	1.081014	Prob. Chi-Square (2)	0.5825
The ARCH heteroscedasticity test	F-STAT	1.846035	Prob. F(3,33)	0.1580
	Obs*R-squared	5.317073	Prob. Chi-Square(3)	0.1500
The Ramsey RESET			Df	Prob
	T-STAT	1.867059	14	0.0830
	F-STAT	3.485911	(1, 14)	0.0830
Normality Test	Jaq-Bera	2.8184	PROB	0.2443

Stability Diagnostics

The Cumulative Sum (CUSUM) Test and CUSUM of Square Test indicates the stability of the findings generated from the estimations of the long-run and short-run parameters for NARDL model.

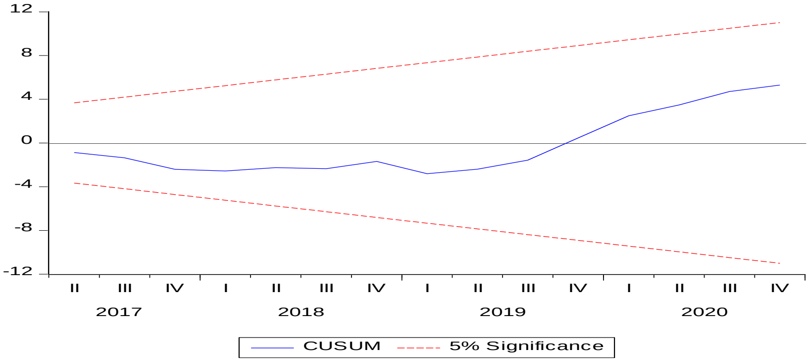


Figure 7: Lgdp Cusum Test

Source. Author's compilation

The CUSUM and CUSUMSQ statistic for LGDP in model one falls inside the critical bands of the 5% significance interval of parameter stability. The finding validates the lack instability in the coefficients of the estimates of the model throughout the period of the investigation.

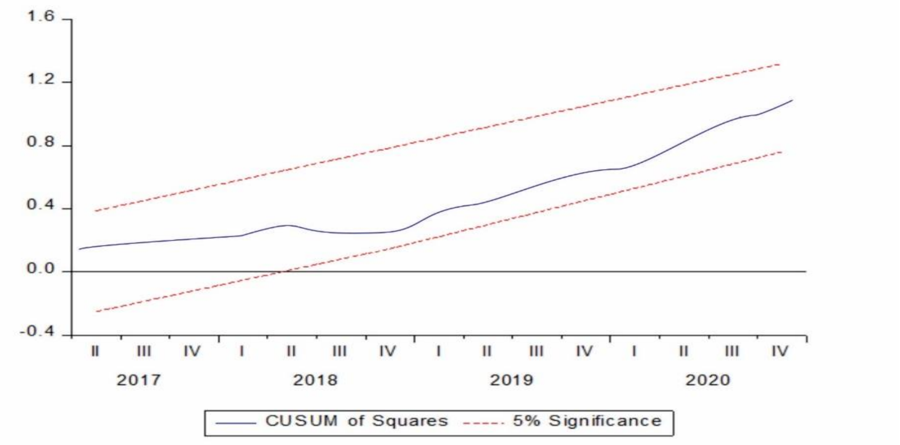


Figure 8: Lgdp Cusumsq Test

Source. Author's compilation

V. Conclusions and Recommendations:

This paper used NARDL approach to examine the asymmetric relationship of GenCos natural gas consumption and the growth of Nigerian economy from year 2010 to year 2020. To ascertain the reliability of the results, we performed ADF unit root test. The bounds test for co-integration was done to ascertain the features of the model. The short-term and long-term characteristics of the model were then carried out. Wald tests to confirm asymmetry were performed on both short-run and long-run coefficients. Statistical diagnostic tests and stability diagnostic tests, such as the Cumulative Sum (CUSUM) Test, CUSUM Square tests were also conducted to confirm the robustness of the model.

The empirical findings of the research revealed that the natural gas consumption by power generating companies in Nigeria is asymmetric with the growth of Nigerian economy over long period and symmetric in short duration. It further indicates that increase in gas consumption by GenCos increases Nigeria GDP and decrease in their consumption decreases the country's GDP. Therefore, the need for a stable, sustainable and increasing supply of natural gas to power plants is vital to facilitate the development of the economy of Nigeria.

We recommend that the government and policy makers, which include NUPRC and NMDPRA should implement measures to enhance the infrastructure for gas production, storage and transmission to power plants to stop the recurrence inadequacy of gas supply to power plants, thereby increasing gas consumption by electric power plants. The government should encourage private sector participation in the gas industry and electricity generation to boost gas production and consumption through liberalization of the sector. This will lead to increased power supply, gas production and consumption, thereby contributing positively to the country's economic growth. This recommendation agrees with that of Sohail et al, 2021 for Pakistan that concluded that energy security is important in sustaining the growth of the economy especially in developing countries that are starved of energy and further recommended enhanced consumption of relatively clean energy resources.

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