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# Analysis of the Impact of Clean Energy and Non-Clean Energy on Economic Growth in Nigeria Using Non-Linear Approach

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**ABSTRACT**

*Nigeria is heavily dependent on traditional biomass energy, and modern energy services play only a small direct role in the macroeconomy, which suggests that a constraint is in place. Energy can be seen as a special type of commodity in that its consumption has effects on the environment and human health and thus can affect human welfare. This study conducted an empirical analysis to examine the influence of clean and non-clean energy on economic growth in Nigeria. The analysis employed a non-linear approach and covered the period from 1990 to 2022, which was determined based on data availability. The paper utilized the Non-Linear Autoregressive Distributed Lag (NARDL) model because it permits the underpinning variables of study to shift across period. It also includes an error correction process or a mechanism that considers asymmetries in long-run co-integration. Evidence has shown that the adverse asymmetric effects of Petroleum and other Liquid Product on GDP, is in both the short and long run, it indicates that depending on petroleum could have consequences, potentially impeding overall economic stability or expansion. The asymmetrical effect of Liquefied Natural Gas on GDP is in the long run only. It highlights the potential of natural gas as a more stable and beneficial energy resource compared to crude oil. The findings on Hydropower are indicating asymmetric effects in both short run and long run, this may demonstrate the advantages of hydropower in its contribution to the energy supply. The asymmetrical impact of Labour Force on GDP is in the long run. It points to potential underutilization of human resources. This could be due to underemployment, lack of industrial diversification, and insufficient investment in education and vocational training. The asymmetrical impact of Gross Capital Formation on GDP is in both the short and long run. It underscores the importance of infrastructure investment. Overall, the analysis indicates that in order for Nigeria to attain consistent economic growth, it is imperative to adopt a well-rounded strategy that encompasses energy sector restructuring, economic diversification, and the enhancement of human capital.*

## I. Introduction

Modern economic growth in developed and developing nations has been intrinsically linked to increased energy usage, and this relationship is likely to hold as long as people depend on energy for survival and comfort. Some studies have found that clean energy has a positive impact on economic growth, while others have found that non-clean energy has a positive impact. A 2017 study by the International Renewable Energy Agency (IRENA) found that clean energy can contribute to economic growth in Nigeria by increasing energy access, reducing energy costs, and stimulating innovation. The study found that renewable energy could create up to 2.5 million jobs in Nigeria by 2030. A 2018 study by the World Bank found that non-clean energy, such as oil and gas, has also had a positive impact on economic growth in Nigeria. The study found that oil and gas exports have helped to finance government spending and infrastructure development. At present, Nigeria is heavily dependent on traditional biomass energy, and modern energy services play only a small direct role in the macroeconomy, which suggests that a constraint is in place. Energy can be seen as a special type of commodity in that its consumption has effects on the environment and human health and thus can affect human welfare. The type of energy being consumed has differing effects on welfare, and herein lies the issue of clean and non-clean energy. Nigeria has been adversely affected by environmental damage caused by the production of oil, which has led to degradation of its natural environment as well as many public health problems. The money accrued from profitable oil industries has also been squandered by corrupt governments and officials. It is thought that clean energy sources are less damaging to the environment and public health and can provide a more stable platform for economic development. The oil industry has also been associated with Dutch Disease in Nigeria. It is said that the wealth generated by the industry has had adverse effects on exchange rates and prevented development in other industries. These are all important issues, but to date, there has been little research into the effects and potential policy implications of energy types in Nigeria.

Many countries in Sub-Saharan Africa face the challenge of poor electricity access and rely on non-clean sources of energy, such as fossil fuels and diesel-powered generators. For example, in Nigeria only 56% of the population have access to electricity. As a result, efforts are being made in many countries to increase investment in clean energy sources with the goal of improving electricity access and reducing greenhouse gas emissions. There is now substantial research which suggests that using energy that is clean and renewable can have positive impacts on economic growth and human development as well as having the potential to reduce poverty. In Nigeria, which is the focus of this study, the government has plans to ensure that the country meets the United Nations' sustainable energy goals. This includes a target to achieve 100% electrification using renewable energy sources. As the research progresses, further details about the specific targets, policies and current clean-energy capacity in Nigeria can be given. This background gives an overview of the importance of understanding the impact of different types of energy on economic growth and provides a context for the more specific research aims of this study.

Nigeria, with a population of 187 million, is the most populous country in Africa and the 7th most populous in the world. It accounts for over 47% of West Africa's population and has one of the largest populations of youth in the world. Nigeria is the largest oil producer in Africa, the 6th largest oil producer in the world, and has vast oil reserves. Despite this, Nigeria has unreliable power and its electricity consumption per capita is 144kWh, compared to the world's average of 3044kWh. This is widely regarded as a result of mismanagement of the energy sector, as well as corruption. Energy poverty has been addressed as a serious barrier to Nigeria's development and poverty alleviation through UN sustainable development goals, and therefore energy is something that is critical to Nigeria's economic development and poverty alleviation. With energy demand growing at 8% per year, Nigeria's peak demand is expected to reach 40GW by 2020. Meanwhile, Nigeria has been trying to diversify its economy away from oil through the National Development Plan and Vision 2020. One of the ways this would be achieved is through developing the minerals and mining sector, agriculture, and facilitating growth in Small and Medium Enterprises. This diversification strategy was formulated with an understanding that due to various reasons, relying on oil has hindered Nigeria's economic development and has not translated oil wealth into improved standard of living for Nigerians. With this in mind, it is worth looking at whether clean energy and non-clean energy have different effects on Nigeria's economic growth. This is because we would expect that clean energy and non-clean energy have different relationships to the development of different sectors, creation of employment, and formation of human capital; and therefore, direct and indirect effects on economic growth.

In recent times, clean energy deployment has encountered numerous obstacles in its quest to out seat fossil fuels as the predominant source of electrical power worldwide. The plunge in universal oil and gas prices, which had been exacerbated by greenhouse gas-induced environmental standards in various nations, has led to the consistent reduction of energy investments. Sturdy encouragement and backing of fossil fuel industries by varied governments, and constant regulatory amendments surrounding the renewables segment, in response to fifty-fifty economics and reliability concerns on electricity supply, necessitate that clean energy systems authenticate and vindicate their economic robustness and steadiness in an exceedingly more competitive energy market. Non-clean energy or, in many cases, high energy consumption has caused several examples of damage to the environment. It is no doubt that the increased level of $CO_2$ in the atmosphere has increased energy retention and has caused global warming. Known problems are that with the use of fossil fuels, there is the cause of acid rain, damage to natural vegetation, and a variety of health problems in humans and animals. Steps and measures around the world have been taken to try and combat these issues. This results in the lower productivity of energy and, in some cases, a decrease in energy consumption which tries to reduce the effects of detrimental energy on the environment. This has resulted in higher costs of energy. The effects are the direct opposite of what is expected. In Nigeria, the elasticity of energy consumption with respect to GDP and the price of energy have evidenced a change for the lower, but this is due to the detrimental effects on the environment and taking measures to reduce this. This form of behavior will attribute to yet another bi-directional causal relationship.

The importance of this study cannot be overstated a change in energy sources can have far-reaching effects on the economy, especially in a developing nation. An increase in energy supply, if the increase is exogenous and not a result of economic growth, is often thought of as a catalyst for economic growth. Nigeria has abundant energy resources and currently has an energy output substantially lower than would be predicted. It is thought that restricted supply of energy has been a limiting factor to growth in many of Nigeria's industries. Step increases in energy input, which could be simulated in this research by an increase in productivity of energy use, can lead to structural change and further development in various sectors of an economy (Osiobe, 2019).

The objective of this study is to analyze the impact of clean energy and non-clean energy on economic growth in Nigeria using a non-linear approach. The purpose of this study is to systematically quantify and compare the effects of energy sources on growth in a developing country and to provide insight on how better energy policy, planning, and pricing can foster more robust and sustainable economic growth. The motivation comes from recent controversy over the choice of energy sources, and Nigeria's simultaneous struggle to implement suitable energy infrastructure and to foster economic development. Energy and growth are clearly important topics for Nigeria, yet the country currently faces a chronic energy crisis, impeding sustained economic growth.

This study aims to analyze the impact of energy consumption from clean and non-clean sources on economic growth. The context within which the idea of the study is motivated by the unevenly distributed resource endowments between different regions in Nigeria and the prospects of regional economic development. It has been suggested that conventional neoclassical models of economic growth are not applicable to developing countries because many are simply dualistic economies, sometimes with a large modern sector and a much larger traditional sector, or because it is invalid to aggregate over regions with different factor endowments. Traditional models have had difficulty explaining the patterns of development that occur in these countries. The hypothesis is the process of creative destruction: i.e. new growth occurs when resources are reallocated from less to more productive uses through a process that may involve upheaval as new sectors emerge and absorb resources from declining or less productive sectors. Simulation studies provide convincing high-quality proof that this can cause takeoff from a low growth path to a higher growth sustainability at a continuing rate. This has direct relevance for the expected impact of new growth theory. But before specifying a model, we should make a distinction between different types of economic growth. Consider a country that has resource endowments with potential for high growth in the modern sector but has been trapped in a low (or zero) growth equilibrium because all resources are employed in subsistence agriculture to meet high population growth rate. An unexpected adverse terms of trade shock in the modern sector may cause a shift to more labor-intensive production methods and rural-urban migration, in search of higher wages, causing movement of resources out of agriculture and into the modern sector. This country is moving from an agriculture-led path of economic growth to the non-traditional resource-led path. With new growth theory, we widely expect that the shift to more productive use of resources will eventually cause acceleration in the growth rate to a new equilibrium. This is very similar to the process of structural transformation between and within regions in Nigeria. Numerous previous studies have illustrated that the nexus between energy and growth has been extensively researched. Yet, scholars have no consensus on a definitive hypothesis to describe the relationship within the energy-growth nexus. Furthermore, many of these studies possess inherent shortcomings. For instance, the Environmental Kuznets Curve (EKC) model, commonly employed in these studies, has several weaknesses. One critical issue with the EKC model is that it often overlooks essential factors such as labor force and capital, which are crucial for understanding the nexus between energy types both (clean and non-clean) and economic growth.

This study also aims to bridge these gaps by explicitly including these pivotal factors to analyze the relationship between energy consumption and economic growth in Nigeria. The current research will also explore potential innovations in addressing the impacts of both clean and non-clean energy on economic growth, employing a non-linear approach that would allow for the possibility of a curvilinear relationship between the variables. This means that the relationship between the variables could be positive at some levels, but negative at others. For example, it is possible that the impact of clean energy on economic growth could be positive at low levels of clean energy consumption, but negative at high levels of clean energy consumption. This is because the costs of investing in clean energy technologies could outweigh the benefits at high levels of clean energy consumption. A non-linear approach would also allow for the possibility of threshold effects. This means that the relationship between the variables could change at certain levels. For example, it is possible that the impact of clean energy on economic growth could be positive only after a certain threshold level of clean energy consumption is reached. By doing so, this study not only contributes to the academic discussion but also provides varied insights that could guide policy formulation and strategic planning in Nigeria's energy and economic sectors. Thus, it aims to present a more comprehensive understanding of how different types of energy consumption affect the nation's economic trajectory, highlighting the importance of integrating sustainable energy solutions into Nigeria's economic development plans.

## II. Litreture Review

### Theoretical Review

### The Environmental Kuznets Curve Theory (EKC)

Environment Kuznets curve (EKC) hypothesis was developed in the 1950s and 1960s. It is worth noting that this theory is named after Simon Kuznets not because he contributed to the theory but because his work on the relationship between income inequality and economic growth in 1955 produced a similar inverted U-shape curve with the EKC hypothesis' findings. Environment Kuznets curve (EKC) hypothesis focused on the nexus between emissions and economic activities. The theory of the Environmental Kuznets Curve stems out of the issues about natural resources depletion, its environmental impact and also the economic growth sustainability. The Club of Rome's report on "The Limits to Growth", that economic growth significantly impacts the environment negatively, and the conclusion that the world will collapse in future when the global economy reaches her physical limits in terms of the extraction of nonrenewable resources, environmental pollution and agricultural production, triggers series of research about the EKC theory.

This theory is relevant to this study because it explains the interconnectivity and causal relationship among income per capita, natural resources depletion and environmental pollution concerning phases of development in the society. This theory is relevant to the objectives of this study because it investigates and explains the relationship between economic growth and energy as a result of energy consumed to exploit natural resources. This theory can be applied in the case of Nigeria, where the desire for growth and development makes her focus on crude oil exploitation and neglect of other sustainable sources of revenue. Continuous exploitation of crude oil leads to increased environmental degradation and pollution due to oil spillage and greenhouse gas emission, the resultant effects of which are not environmentally friendly. Diversification, as suggested by this theory, will bring about an increase in demand for clean energy consumption and reduction in carbon emission into the ozone layer, harnessing other productive but underemployed or under-engaged sectors, e.g., services, while the country continues to experience a growth at a steady and desirable pace.

### Emperical Review

The impact of clean energy, non-clean energy, and economic growth in Nigeria is a complex issue that has been the subject of much research in recent years. However, both clean and non-clean energy can have negative environmental impacts. For example, the use of fossil fuels can contribute to climate change. Therefore, it is important to find a balance between economic growth and environmental protection. One way to do this is to invest in clean energy technologies that are both environmentally friendly and economically viable. For example, solar and wind power are clean energy sources that have the potential to provide clean and affordable energy to Nigeria. Another way

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to balance economic growth and environmental protection is to implement policies that promote energy efficiency. Energy efficiency measures can help to reduce energy consumption and emissions, while also saving businesses and consumers money. The nexus between clean energy, non-clean energy, and economic growth in Nigeria is complex. However, by investing in clean energy technologies and promoting energy efficiency, Nigeria can achieve economic growth while also protecting the environment. A non-linear approach would also allow for the possibility of threshold effects. This means that the relationship between the variables could change at certain levels. For example, it is possible that the impact of clean energy on economic growth could be positive only after a certain threshold level of clean energy consumption is reached. There have been a number of studies that have used non-linear approaches to analyze the impact of clean energy, non-clean energy, and economic growth in Nigeria. These studies have found that the relationship between clean energy and economic growth is complex and can vary depending on the level of clean energy consumption.

Another study, by Usman (2017), found that the impact of clean energy on economic growth in Nigeria is asymmetric. This means that the impact of clean energy on economic growth is different depending on whether the change in clean energy consumption is positive or negative. The study found that a positive shock in clean energy consumption has a positive impact on economic growth, while a negative shock in clean energy consumption has a negative impact on economic growth. The results of these studies suggest that the impact of clean energy on economic growth in Nigeria is complex and can vary depending on the level of clean energy consumption. However, both clean and non-clean energy can have negative environmental impacts. For example, the use of fossil fuels can contribute to climate change. Therefore, it is important to find a balance between economic growth and environmental protection. One way to do this is to invest in clean energy technologies that are both environmentally friendly and economically viable. For example, solar and wind power are renewable energy sources that have the potential to provide clean and affordable energy to Nigeria. Another way to balance economic growth and environmental protection is to implement policies that promote energy efficiency. Energy efficiency measures can help to reduce energy consumption and emissions, while also saving businesses and consumers money. The nexus between clean energy, non-clean energy, and economic growth in Nigeria is complex. However, by investing in clean energy technologies and promoting energy efficiency, Nigeria can achieve economic growth while also protecting the environment. Sugiawan and Managi (2016) stated that the environmental Kuznets curve is useful for examining the relationship between economic expansion and energy pollution.

Shafiei and Salim (2014) found that the use of clean energy decreases CO2 emissions, whereas the use of non-clean energy leads to a significant increase in CO2 emissions. According to Seck et al. (2015), a non-energy demanding industry will experience a significant decrease in energy consumption and a substantial impact on the overall energy intensity as a result of a structural adjustment. Therefore, numerous organizations, policymakers, and government agencies have undertaken empirical and theoretical study to explore the importance and correlation between clean energy and economic growth. The majority of these studies investigated the relationship between CO2 emissions and GDP per capita, using a quadratic model.

Pao and Li (2014) examined the relationship between economic growth and the use of both clean and non-clean energy in the economies of Mexico, Indonesia, South Korea, and Turkey, collectively known as MIST. The chosen approach was panel cointegration. The findings indicate that there is a long-term causal relationship between the usage of clean energy and economic growth. Additionally, there is evidence of positive feedback causality in the short term. Clean energy sources can lead to a reduction in the usage of fossil fuels over time. However, in the near term, there may be a negative feedback effect. In 2014, Zhang et al. conducted a study on the potential for collaboration in clean energy between the United States of America and China. Their discovery indicates that this collaboration can stimulate economic progress, reduce carbon emissions, enhance environmental conditions, promote sustainable growth, and generate reciprocal advantages for both nations. Sbia et al. (2014) established a link between economic growth and many factors such as foreign direct investment, trade openness, carbon emissions, and clean energy in the UAE. The employed technique was the autoregressive distributed lag approach to cointegration. Their research indicates that trade openness, carbon emissions, and foreign direct investment lead to a decrease in energy consumption, whereas clean energy and economic growth have a favorable impact on energy consumption.

In addition, Awodumi and Adewuyi (2020) examine the influence of non-clean energy usage on both economic growth and CO2 emissions in the top five oil-producing countries in Africa during the period of 1980-2015. They categorized non-clean energy as either petroleum or natural gas. After confirming the presence of nonlinearity and structural break in the data, it employed the Non-linear Autoregressive Distributed Lag (NARDL) approach for analysis. The findings indicated that the per capita consumption of both energy sources had a disparate effect on both economic growth and carbon emission per capita in all nations except Algeria. For example, in the case of Nigeria, the rise in non-clean energy sources resulted in a decline in economic growth but led to an enhancement in environmental quality. In Angola, the utilization of non-clean energy sources contributes to economic growth.

However, the impact on environmental quality is diverse, fluctuating in accordance with energy use. The expansion of these energy sources had a little impact on environmental pollution, as it concurrently contributed to economic prosperity. Kahia and Aissa (2014) conducted a study to examine the influence of clean and non-clean energy consumption on economic growth in 13 net-oil exporting nations in the Middle East and North African (MENA) region from 1980 to 2012. Nevertheless, the fragmented energy sources had a favorable and substantial effect. Unlike the findings of Azam et al. (2021), it was shown that clean energy (electricity) had a greater influence on economic growth compared to non-clean energy (petroleum). In separate research conducted on West Africa from 1995 to 2014, Maji et al. (2019) employed the DOLS, FMOLS, and OLS methods to demonstrate that the utilization of renewable energy and biomass hinders economic progress. According to Twerefou et al. (2018), the outcome was ascribed to the origin and characteristics of the renewable energy utilized in West Africa, primarily derived from wood biomass. Furthermore, they lamented the insufficient utilization of cleaner energy sources such as wind, solar, and hydropower in the area.

Furthermore, Ranjan et al. (2017) analyze the link between energy consumption and economic growth in the BRICS countries (Brazil, Russia, India, China, and South Africa) from 1990 to 2012 using a multivariate panel framework. The findings indicate a sustained connection between GDP per capita, clean energy consumption, non-clean energy consumption, and gross fixed capital formation. Additionally, there is a one-way causality from economic growth to both clean and non-clean energy consumption, hence validating the conservation hypothesis. The findings suggest that economic expansion plays a crucial role in driving energy consumption in the BRICS countries. Consequently, an increase in economic growth will lead to a corresponding increase in energy consumption, and conversely. Bölük and Mert (2014) discovered a correlation indicating that the adoption of renewable energy in 16 EU nations is an effective approach for promoting both environmental and economic progress.

The aforementioned studies demonstrate that the connection between energy and growth has been extensively studied. However, there is still a lack of agreement among scholars on a valid hypothesis that accurately describes the relationship between the energy-growth nexus. Additionally, the majority of the research have certain limitations. The bulk of research have utilized the Environmental Kuznets Curve (EKC) model, which has several inherent shortcomings. One such weakness is that the model fails to consider crucial aspects like labor force and capital, which are vital for comprehending the relationship between energy (clean and non-clean) and economic growth. The inclusion of these elements in the study was deliberate in order to examine the linear relationship. This article explores prospective advancements that examine the relationship and effects of clean energy and non-clean energy on economic growth in Nigeria. The study uses a linear approach spanning from 1990 to 2022.

## III. Methodology

This study adapts the model of Pao, Li & Fu (2014), while retaining the labour and capital stock as the control variables for our model, Liquefied Natural Gas (LNG) as well as Petroleum and other Liquid (POL) are used to proxy non-clean energy consumption and Hydropower (HP) is used to proxy clean energy consumption. Only hydropower is chosen as a proxy for clean energy because data of others such as Solar and Wind are not available for a reasonable number of years in Nigeria. Consequently, the econometric model for

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clean energy and economic growth and non-clean energy and economic growth are presented is presented as in equation (1);

$$gdp_t = f(pol_t, lng_t, hp_t, lf_t, gcf_t) \quad (1)$$

Where *gdp* is the real gross domestic product, *pol* is the petroleum and other liquid, *lng* is the liquefied natural gas, *hp* is the hydroelectric power, *lf* is the labour force, and *gcf* is the gross capital formation. It is expected that the three energy variables should increase domestic income or output (real GDP) in the short and long run. Also, the increase in the active labour force is expected to contribute to the economy's growth and the accumulation of capital. On the issue of historical data on the variables, data availability is among the significant challenges in developing countries, from which Nigeria is not exempted. Therefore, the historical data for this study covers the period of 32 years (1990 – 2022), and their sources are presented in detail in Table 3.1.

**Table 3.1: Data sources**

| Variable | Source |
|---|---|
| GDP | World Banks Development index |
| Petroleum and other liquid | World Banks Development index |
| Liquefied natural gas | World Banks Development index |
| Hydropower | World Banks Development index |
| Labour force | World Banks Development Index |
| Gross capital formation | World Banks Development Index |

Source: Author's Computation

The data are first examined through the lens of descriptive analysis to investigate the significant statistical attributes of the data, including maximum, minimum, mean, standard deviation, skewness and kurtosis. To test the normality of the data sets, Jarque-Bera statistics of the variables with their associated p-values are also examined. The econometrics analysis begins with examining the time-series properties of the variables concerning the presence of unit root and the order of integration using the Augmented Dickey-Fuller (ADF) test. The asymmetric Non-Linear Autoregressive Distributed Lag (NARDL) model is employed to analyse the short and long-run impacts of clean and non-clean energy on economic growth in Nigeria. Based on the above discussion, the NARDL framework for equation (3.1) above is given as

$$\Delta\log(gdp_t) = \phi_0 + \sum_{i=1}^{q}\phi_{1i}\,\Delta\log(gdp_{t-1}) + \sum_{i=0}^{q}\phi_{2i}\,\Delta\log(pol_{t-i}) + \sum_{i=0}^{q}\phi_{3i}\,\Delta\log(lng_{t-i}) + \sum_{i=0}^{q}\phi_{4i}\,\Delta\log(hp_{t-i}) + \sum_{i=0}^{q}\phi_{5i}\,\Delta\log(lf_{t-i}) + \sum_{i=0}^{q}\phi_{6i}\,\Delta\log(gcf_{t-i}) + \eta_1\log(pol_{t-1}) + \eta_2\log(lng_{t-1}) + \eta_3\log(hp_{t-1}) + \eta_4\log(lf_{t-1}) + \eta_5\log(gcf_{t-1}) + v_t \quad 2$$

The terms with the summation signs represent the short-run (ECM) dynamics with their respective short-run coefficients ($\phi_1$- $\phi_6$). The coefficients $\eta_1$ – $\eta_5$ are the long-run multiplier corresponding to the long-run relationship. $\phi_0$ is the intercept, vt is the white noise error, Δ is the first difference operator, and *p* and *q* are the lag length for the conditional ARDL model. To test the existence of a long-run relationship for the above model, the thesis conducts an F-test for a joint significance of the coefficient of the lagged levels by using ordinary least square (OLS). Thus, using an F-test, test the null hypotheses of no cointegration; $H_0$:$\eta_1 = \eta_2 = \eta_3 = \eta_4 = \eta_5 = 0$ against the alternative hypothesis of the existence of cointegration; $H_1$: $\eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq \eta_5 \neq 0$.

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## IV. Data Analysis

**Table 4.1: Descriptive statistics of variables**

| | Mean | Std. Dev. | C.V. | Max | Min | J-B | Obs |
|---|---|---|---|---|---|---|---|
| gdp | 2.36E+11 | 1.80E+11 | 0.763 | 5.47E+11 | 2.78E+10 | 3.607 | 32 |
| pol | 0.638348 | 0.162045 | 0.254 | 0.94934 | 0.43155 | 4.846* | 32 |
| lng | 99774.5 | 59286.51 | 0.594 | 175819 | 30326 | 4.120 | 32 |
| hp | 6221.375 | 991.9376 | 0.159 | 8234 | 4387 | 1.840 | 32 |
| lf | 47412448 | 9709509 | 0.205 | 64479317 | 31787602 | 1.855 | 32 |
| gcf | 5.01E+10 | 3.26E+10 | 0.651 | 1.46E+11 | 1.23E+10 | 6.818** | 32 |

Source: Author's computation

Table 4.1 above shows the descriptive statistics for the gross domestic product (gdp), petroleum and other liquid (pol), liquefied natural gas (lng), hydropower (hp), the labour force (lf), and gross capital formation (gcf) in Nigeria respectively, from 1990 to 2022. It can be observed that the empirical mean for all the variables is positive. The coefficient of variation (C.V.) is used to measure the relative dispersion of the variables and is calculated as the standard deviation divided by the mean. A more significant coefficient of variation shows that the variables have a more considerable variation than the other. It can be deduced from the table that, among the energy variables, hydropower has the lowest degree of variation, and liquefied natural gas (lng) has a higher variation than petroleum and other liquid (pol). The high degree of variation in the gross domestic product reflects the frequent degree of the business cycle in the Nigerian economy. The lower degree of variation in the labour force tells a story; it implies that the labour force of Nigeria has not been faring well over the decades, despite the high rate of capital accumulation in the economy. The probability value of the Jarque-Bera (J-B) normality test is statistically significant for petroleum and other liquid (pol) and gross capital formation (gcf), and this implies that they are not normally distributed. However, since we are using a fairly large sample size, the issue of normality in data will not pose a problem due to the law of large sample size; the parameter estimates based on the data will converge to their true value asymptotically.

**Table 4.2: Pair-wise correlation matrix**

| | Gdp | Pol | Lng | hp | lf | gcf |
|---|---|---|---|---|---|---|
| gdp | 1 | | | | | |
| pol | 0.713*** | 1 | | | | |
| lng | 0.826*** | 0.704*** | 1 | | | |
| hp | 0.106 | 0.308* | 0.425** | 1 | | |
| lf | 0.912*** | 0.725*** | 0.851*** | 0.353** | 1 | |
| gcf | 0.861*** | 0.731*** | 0.764*** | 0.153 | 0.896*** | 1 |

Source: Authors' computation.
**** p < 0.01; ** p < 0.05; * p < 0.1*

Table 4.2 depicts the pairwise correlation between the variables; gross domestic product (gdp), petroleum and other liquid (pol), liquefied natural gas (lng), hydropower (hp), the labour force (lf), and gross capital formation (gcf). It can be generally observed from the table that all the variables positively correlated with each other. Looking at the first column, only hydropower does not significantly correlate with the gross domestic product, and it has the lowest degree of association with the gross domestic product. Among the energy variables, liquefied natural gas has the highest degree of association with the real gross domestic product. Looking at the correlation among the energy variables, the correlation between petroleum-other-liquid and liquefied gas is more than that of petroleum-other-liquid and hydropower. The degree of correlation between hydropower and liquefied gas is weak but significant.

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**Table 4.3: ADF unit root test result**

| Variable | Level | | first difference | | Remark |
|---|---|---|---|---|---|
| | C | c & t | c | c & t | |
| log(gdp) | -0.544 | -1.681 | -4.278 | -4.172 | *I*(1) |
| log(pol) | -1.001 | -2.289 | -6.922 | -7.183 | *I*(1) |
| log(lng) | -1.258 | -2.873 | -6.110 | -6.016 | *I*(1) |
| log(hp) | -3.468 | -3.452 | -6.879 | -6.704 | *I*(0) |
| log(lf) | -1.456 | -1.689 | -3.535 | -3.434 | *I*(1) |
| log(gcf) | 0.233 | -3.079 | -3.952 | -4.103 | *I*(1) |

Source: Authors' computation.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 4.3 depicts the Augmented Dickey-Fuller unit root test results for the variables. Two different assumptions are taken into account in the testing procedure; the first assumption is that only constant, c, is present in the variables, while the second assumption holds that both trend and constant, c + t, are present in the testing procedure. It has to be noted that when a variable with a trend assumption becomes stationary, i.e. at level, this implies that the variable is a trend stationary variable rather than a stationary difference variable. It is often appropriate to include both time and trend to capture the complexity in the data-generating process of a variable; a time, traces of randomness remain in some detrended macroeconomic variables. It can be deduced from the result that all the variables are first-order integrated variables, i.e. *I*(1), except hydropower which is shown to be stationary, i.e. *I*(0). The general idea is that there is a possibility for the integrated regressors to cointegrate with the integrated dependent variable; however, there is also a stationary regressor, and the implication is that the common trend in the integrated variables will cancel out and the resultant cointegrating vector with the stationary regressors will result to a stationary residual. The employment of the NARDL model helps to easily carry out such analysis by accommodating integrated and stationary regressors and this aids in achieving the objectives of this study.

**Table 4.4: Asymmetric ARDL (NARDL) bound-test**

| Lag structure | F-stat | C.V. | | |
|---|---|---|---|---|
| ARDL(1,0,1,1,1,0,0,1,1) | 8.773 | Sig. | I(0) | I(1) |
| | | 10% | 2.26 | 3.34 |
| | | 5% | 2.55 | 3.68 |
| | | 1% | 3.15 | 4.43 |

Source: Authors' computation.

Table 4.4, shows the bound test result for testing the long-run relationship between the real gross domestic product (gdp), positive petroleum and other liquid ($pol^+$), negative petroleum and other liquid ($pol^-$), positive liquefied natural gas ($lng^+$), negative liquefied natural gas ($lng^-$), positive hydropower ($hp^+$), negative hydropower ($hp^-$), the labour force (lf), and gross capital formation (gcf) respectively. The decision rule follows exactly as in the symmetric ARDL in section 4.4 above. It can thus be deduced from the results show that the calculated F-stat: 8.773 is significant at 10%, 5%, and 1% levels of significance; hence, we conclude that there exists a long-run relationship between real gross domestic product (gdp), positive petroleum and other liquid ($pol^+$), negative petroleum and other liquid ($pol^-$), positive liquefied natural gas ($lng^+$), negative liquefied natural gas ($lng^-$), positive hydropower ($hp^+$), negative hydropower ($hp^-$), the labour force (lf), and gross capital formation (gcf). The asymmetric long-run and the short-run results are presented and discussed in the section that immediately follows.

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**Table 4.5: NARDL short and long runs estimates**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| $pol_t^+$ | 1.077 | 0.368 | 2.927 | 0.011* |
| $pol_t^-$ | -4.529 | 0.962 | -4.709 | 0.000*** |
| $lng_t^+$ | 0.452 | 0.071 | 6.371 | 0.000*** |
| $lng_t^-$ | -0.466 | 0.365 | -1.276 | 0.223 |
| $hp_t^+$ | 0.039 | 0.276 | 0.142 | 0.889 |
| $hp_t^-$ | 3.397 | 0.940 | 3.613 | 0.003*** |
| $\log(lf_t)$ | 6.503 | 2.668 | 2.437 | 0.029** |
| $\log(gcf_t)$ | 0.618 | 0.093 | 6.668 | 0.000*** |
| $\Delta pol_t^+$ | 0.478 | 0.262 | 1.826 | 0.089* |
| $\Delta pol_t^-$ | -1.546 | 0.185 | -8.368 | 0.000*** |
| $\Delta lng_t^+$ | 0.037 | 0.028q | 1.327 | 0.206 |
| $\Delta lng_t^-$ | 0.087 | 0.097 | 0.894 | 0.387 |
| $\Delta hp_t^+$ | 0.017 | 0.124 | 0.141 | 0.890 |
| $\Delta hp_t^-$ | 1.508 | 0.194 | 7.792 | 0.000*** |
| $\Delta\log(lf_t)$ | 0.058 | 0.697 | 0.084 | 0.935 |
| $\Delta\log(gcf_t)$ | 0.929 | 0.047 | 19.881 | 0.000*** |
| $const.$ | -45.258 | 4.077 | -11.100 | 0.000*** |
| $trend$ | -0.127 | 0.011 | -11.677 | 0.000*** |
| $ecm_{t-1}$ | -0.444 | 0.040 | -11.139 | 0.000*** |

Source: Authors' computation.
**** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$*

Table 4.5 above shows the estimated long-run and short-run asymmetric impact of petroleum and other liquid (positive and negative petroleum and other liquid), liquefied natural gas (positive and negative liquefied natural gas), and hydropower (positive and negative hydropower) with labour force and gross capital formation as the control variables on the real gross domestic product. It can be seen that positive petroleum and other liquid has a significant positive impact on the real gross domestic product in the short-run and long-run; the result shows that a one percent increase in the positive petroleum and other liquid brings about 0.48% and 1.08% units to increase in the real gross domestic product in the short-run and long-run respectively. On the other hand, negative petroleum and other liquid have a significant negative impact on the real gross domestic product in the short-run and long-run; the result shows that a one percent increase in the negative petroleum and other liquid brings about 1.55% and 4.53% decreases in the real gross domestic product in the short-run and long-run respectively. The positive liquefied gas significantly impacts real gross domestic product only in the long run; the result shows that a one percent increase in the positive liquefied gas brings about a 0.45% unit increase in the real gross domestic product in the long run. However, there is no statistical evidence that negative liquefied gas impacts the real gross domestic product either in the short or long runs.

There is no statistical evidence that positive hydropower is a determinant of the real gross domestic product both in the short and long runs. However, negative hydropower significantly impacts the real gross domestic product both in the short and long runs; it can be deduced from the result that one percent increase in negative hydropower brings about a 1.51% and 3.40% increase in the real gross domestic product in the short-run and long-run respectively. There is statistical evidence that the labour force impacts real gross domestic product only in the long run; the result shows that a one percent increase in the labour force brings about a 6.5% unit increase in the real gross domestic product in the long run. The gross capital formation is shown to significantly impact real gross domestic product both in the short run and long run; the result shows that one percent increase in the gross capital formation brings about 0.93% and 0.62% units increase in the real gross domestic product in the short-run and long-run. The error correction term shows that given the independent variables, about 44.4% disequilibrium in the gross domestic product due to one-time shock is corrected within a year.

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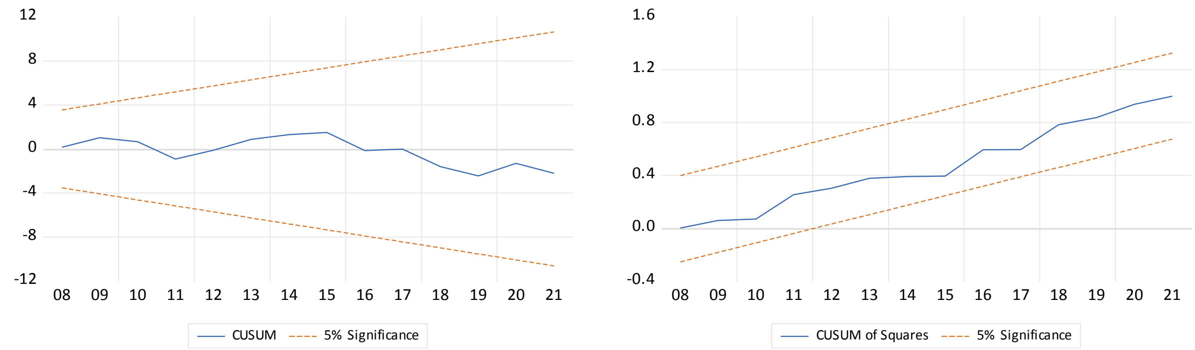

Figure 4.1: NARDL models cusum and cusumsq plots

Figure 4.1 depicts the NARDL model's stability tests graphically. The first panel shows the cumulative sum of residuals (cusum) test and while the second panel shows the cumulative sum of square residuals (cusumsq) test. The smooth blue line shows the test dynamics while the dotted red lines indicated the 5% Bartlett standard error bound. By convention, the null hypothesis is that the regression model is stable over time versus the alternative hypothesis that the model breaks at a point. The rule of thumb is that the blue line or the test line must stay in between the upper and the lower bound for the model to consider stable, otherwise. Fortunately, it can be deduced from the figure that the blue line did not move outside the bound, hence the null hypothesis that the asymmetric ARDL (NARDL) regression model is stable over time.

**Table 4.6: NARDL post-diagnostic tests results**

| Test | Stat. | Prob. |
|---|---|---|
| $\chi^2_{LM}$ | 2.445 | 0.142 |
| $\chi^2_{White}$ | 6.686 | 0.966 |
| $RESET$ | 0.553 | 0.457 |
| $\chi^2_{J-B}$ | 0.817 | 0.665 |

Source: Authors' computation.
**** p < 0.01; ** p < 0.05; * p < 0.1*

Table 4.6 above shows the post-diagnostic tests result to verify the viability of the estimated asymmetric ARDL models. The $\chi^2_{LM}$ is the Breusch-Pagan LM test which is used in testing for the presence of autocorrelation in the estimated time series model's residuals, and its test against the null hypothesis of no autocorrelation. The $\chi^2_{White}$ is the White general test for heteroscedasticity and its test against the null hypothesis of homoscedasticity. The RESET test is performed to check for the linearity specification (about regressors of higher order) of the regression model. The $\chi^2_{J-B}$ is the Jarque-Bera normality test to verify the normality assumption of the models. Based on the computed statistics and their respective probabilities, we may accept the null hypothesis of no autocorrelation of errors, homoscedasticity, egression stability, and normality of residuals, as their respective probabilities are found insignificant.

**Table 4.7**: **Asymmetrical effects test result**

| Null hypotheses; | Stat. | short-run (*s*) | long-run (*l*) | Remark |
|---|---|---|---|---|
| $H_0: pol_t^+ = pol_t^-$ | F-stat | 18.773*** | 53.016*** | *s* & *l* asymmetric effects |
| | Prob. | 0.000 | 0.000 | |
| $H_0: lng_t^+ = lng_t^-$ | F-stat | 0.033 | 6.368** | *l* asymmetric effect |
| | Prob. | 0.859 | 0.000 | |
| $H_0: hp_t^+ = hp_t^-$ | F-stat | 73.031*** | 11.849*** | *s* & *l* asymmetric effects |
| | Prob. | 0.000 | 0.001 | |

Source: Authors' computation.
**** $p < 0.01$; *** $p < 0.05$; * $p < 0.1$

Table 4.7 depicts the asymmetric test results for the NARDL model. It can be deduced from the result that a change in petroleum and other liquid has an asymmetrical effect on the real gross domestic product both in the short and long runs. However, a change in the liquefied gas has an asymmetrical effect on the real gross domestic product in the long run only. Just like in the case of petroleum and other liquid, a change in hydropower has an asymmetrical effect on the real gross domestic product both in the short and long runs.

## V. Discussion, Implication of Findings and Conclusions

### Implication of Findings

The findings drawn from this study have multiple and substantial consequences for policymakers, stakeholders, and Nigeria's broader economic strategy. The analysis provides valuable insights into the dynamics of important economic indicators, such as GDP, petroleum and other liquids (POL), liquefied natural gas (LNG), hydropower (HP), the labor force (LF), and gross capital formation (GCF).

Firstly, economic diversification is crucial for Nigeria due to the adverse asymmetrical effects of petroleum on GDP in both the short and long-term. This indicates an urgent necessity for Nigeria to broaden its economic base. The economy's heavy reliance on petroleum renders it extremely vulnerable to fluctuations in global oil prices, which in turn can result in economic instability. Policymakers ought to prioritize the development of alternative sectors such as agriculture, industry, and services, as these sectors have the potential to generate more consistent and enduring sources of revenue. Implementing diversification strategies can effectively reduce the dangers associated with relying solely on a particular commodity and facilitate the promotion of more extensive economic growth.

Secondly, the asymmetrical effect of LNG on GDP is in the long run only. It highlights the potential of natural gas as a more stable and beneficial energy resource compared to crude oil. Investing in the LNG sector can enhance energy security, reduce environmental impact, and provide a steady source of income through exports. This suggests that the government and private sector should prioritize the development of LNG infrastructure and related industries to capitalize on its economic benefits.

Thirdly, the asymmetrical effects of hydropower on GDP are in both the short and long run. It indicates the need for sustainable and efficient energy policies. Hydropower can contribute to energy supply and economic growth, but inefficiencies and sustainability issues can arise over time. Policymakers should prioritize enhancing the efficacy of hydropower initiatives and investigating alternative renewable energy sources to guarantee enduring sustainability and energy resilience.

In addition, the asymmetrical impact of labour force on GDP is in the long run. It points to potential underutilization of human resources. This could be due to underemployment, lack of industrial diversification, and insufficient investment in education and vocational training. To harness the full potential of the labour force, there is a need for comprehensive reforms in the education system, better alignment of vocational training with industry needs, and policies that encourage job creation in diverse sectors. Developing human capital can significantly enhance productivity and drive economic growth.

Furthermore, the asymmetrical impact of gross capital formation on GDP is in both the short and long run. It underscores the importance of infrastructure investment. Continuous and strategic investment in physical assets like transportation, communication, and industrial infrastructure is essential for supporting economic activities and fostering growth. Policymakers should prioritize infrastructure development to create a conducive environment for business operations and attract further investments.

Finally, regarding policy stability and resilience, the presence of an error correction term indicates that the economy has mechanisms in place to restore equilibrium after disturbances, but the pace of adjustment is comparatively sluggish. This suggests that policies should be formulated with the aim of strengthening economic resilience and minimizing susceptibility to external shocks. Establishing policy consistency and fostering a conducive regulatory framework can contribute to the attainment of enduring economic stability.

## VI. Conclusion and Recommendations

In conclusion, the study's findings highlight the urgent need for economic diversification away from an over-reliance on volatile petroleum to more stable and sustainable sources like natural gas and energy, which show promise in supporting long-term economic stability. The Nigerian government can also promote economic growth while reducing environmental impact by incentivizing businesses to invest in clean energy technologies and making clean energy more affordable for consumers. Furthermore, the underutilization of the labor force points to a pressing need for significant reforms in education and workforce training to harness Nigeria's human capital's potential fully. Implementing these changes will require concerted efforts from policymakers, stakeholders, and the international community to foster an environment that encourages economic resilience, sustainable development, and an improved quality of life for all Nigerians. This strategic shift could redefine Nigeria's economic landscape and set a precedent for other emerging economies facing similar challenges.

**Recommendations**

**Petroleum and Other Liquids (pol)**

i. **Diversification Strategy**: Reduce the economy's over-reliance on petroleum by diversifying into other sectors such as agriculture, manufacturing, and services.
ii. **Oil Price Management**: Enact strategies to effectively handle the consequences of unpredictable fluctuations in global oil prices on the economy, potentially by creating stability funds.
iii. **Investment in Technology**: Promote the adoption of cutting-edge technologies in the oil industry to enhance operational efficiency and mitigate environmental consequences.

**Liquefied Natural Gas (lng)**

i. **Investment in LNG Infrastructure**: Prioritize investments in LNG infrastructure to enhance production, storage, and export capabilities.
ii. **Long-term Contracts**: Secure long-term international contracts for LNG exports to ensure a stable revenue stream.
iii. **Domestic Utilization**: Promote the use of natural gas domestically to reduce reliance on more polluting fossil fuels and support industrial growth.

**Hydropower (hp)**

i. **Efficiency Improvements**: Invest in the modernization and maintenance of existing hydropower plants to improve efficiency and output.
ii. **Sustainability Practices**: Develop and implement sustainable practices to address long-term environmental and operational challenges associated with hydropower.
iii. **Diversification of Energy Sources**: Augment hydropower with additional clean energy sources such as solar and wind in order to establish a well-rounded energy portfolio.

**Labour Force (lf)**

i. **Educational Reforms**: Implement comprehensive reforms in the education system to improve the quality of education and align it with market needs.
ii. **Vocational Training**: Enhance vocational training programs to equip the labor force with skills relevant to various industries, thereby reducing underemployment.
iii. **Job Creation Policies**: Develop policies that encourage the creation of jobs in diverse sectors, ensuring better utilization of the available labor force.

**Gross Capital Formation (gcf)**

i. **Infrastructure Development**: Prioritize continuous investment in infrastructure, including transportation, communication, and industrial facilities, to support economic activities.
ii. **Public-Private Partnerships**: Promote the formation of public-private partnerships to utilize private funding for the advancement of infrastructure projects.
iii. **Efficient Allocation**: Ensure efficient allocation of capital towards high-impact projects that can drive economic growth and development.

**General Recommendations**

i. **Clean Energy Incentives**: Incentivize businesses to invest in clean energy technologies to reduce environmental impact and promote sustainable growth.
ii. **Affordability of Clean Energy**: Enact measures to enhance the affordability and availability of clean energy for consumers.
iii. **International Collaboration**: Foster international collaborations to gain technical and financial support for implementing these recommendations and ensuring sustainable development.

Nigeria can attain a more varied, robust, and enduring economy by implementing these suggestions. This will enhance the standard of living for its population and serve as a favorable model for other developing countries.

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