Nexus of energy efficiency, carbon emission and economic growth in Nigeria

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Abstract
Given rising temperatures, climate change, the alarming increase in energy demand, and the importance of energy efficiency, there is a need for an increasing review subject matter. In this sense, policymakers develop various measures, including renewable adoption and energy efficiency. This study examined the causal effect of oil production and carbon emission from gas flaring on the economic growth rate in Nigeria from 1980-2021. The findings revealed that economic growth and energy consumption significantly increases energy-related emissions. An increase in income level influences investors and industrialists to invest in the industrial sector, increasing production, diversification, and expansion. However, increased production and expansion of industries increase energy demand. Energy demand met by consuming fossil fuel increases energy-related emissions in Nigeria and negatively affects environmental quality. More importantly, carbon emission impedes environmental sustainability and sustainable economic growth in Nigeria. The study is relevant to the post-2015 Sustainable Development Goals agendas for two fundamental reasons: the world needs Sustainable Development Goal 7 – ensuring access to affordable, reliable, sustainable, and modern energy by 2030. (b) Large extractive industries primarily drive growth in Nigeria, and the country's population is expected to double in about 30 years. Energy efficiency for inclusive development is very welcome. This is essential because studies have shown that the increase in unemployment (resulting from the underlying demographic change) would be accommodated by only the private sector, not the public sector.

Keywords: *Carbon emission, Economic growth, Electricity, Energy demand, Environment.*

JEL Classification: O44, Q31, Q34. Q43

INTRODUCTION

Nigeria faces a similar challenge as we move into the coming election year. The ultimate challenge follows the big question of “who to vote for” in our view, it depends on not only the political ideology of the party but often their plans and policies on relevant issues that will affect our lives in the short and long run. This is usually considered how to improve the economic condition of society. Still, another prominent challenge faced in the world generally is the issue of reduction of carbon emissions and zero carbon policies.

Energy efficiency has several environmental benefits and helps to reduce GHG emissions, both direct emissions from fossil fuel combustion or consumption and indirect emissions reductions from electricity generation. Energy efficiency is important in tackling climate change. It helps limited time to achieve mitigation targets, stated by the recent Intergovernmental Panel on Climate Change (IPCC) special report on Global Warming of 1.5oC. Energy efficiency is an important tool the world can use to meet energy service demand with lower energy use. It is important in the pathways of IPCC GHG emissions limiting global warming to 1.5oC (IPCC, 2018).

International Energy Agency (IEA) states energy efficiency can help global energy demand and energy-related CO_2 emissions reduce steadily until 2050. “Efficiency” is the ratio of output to input. World Energy Council (WEC 2006) states energy efficiency is the ratio of energy service output to energy input. Rationing of the target consumption quantity and the actual consumption quantity. The closer the ratio is to one, the more efficient it is. Improving energy efficiency is using as few inputs as possible to gain the largest quantity of service outputs. Energy efficiency is not an isolated measurement. It closely relates to the economy, society, environment, technology, and many other domains. Therefore, Energy efficiency refers to the effective and efficient utilization of energy resources.

With each incoming administration to power promising adequate energy supply, Nigeria's major energy challenges are securing energy supply to meet growing demand, providing everybody with access to energy services, and tackling the causes and impacts of CO2 emission. Specifically, priorities on energy may vary from nation to nation. Developed and rapidly growing economies focus on energy efficiency, energy security of supply, and reducing the CO2 emission impacts of energy use, particularly climate change and air pollution. For developing nations, Nigeria included, securing access to reliable, sustainable, and affordable energy remains a key challenge. Energy poverty, coupled with rapid growth in the human population, has often been identified as one of the main factors of environmental degradation.

Politicians are paying much more attention to climate change and environmental protection due to the dangerous effects of global warming. The political parties now included energy and environmental policies in their agenda, with different ways of improving energy efficiency, reducing energy poverty, and controlling climate change. For instance, the Labour party's agenda is on energy poverty, reducing energy bills, and reducing carbon emissions to zero by 2030. Other parties also include affordable energy supply and insulation and energy efficiency measures in their agenda and better funding system for energy efficiency programs, like, proper building insulation and investment in renewable energy sources. Thus, the question is, how important are energy efficiency and reducing carbon emissions for the population?

Energy is needed to stimulate production, generate income and social development, as well as to reduce the serious health problems caused by the use of fuel wood and other solid fuels. Providing energy supply, securing energy supply, tackling climate change, avoiding air pollution, and reaching sustainable development globally offer opportunities and synergies. Sustainable development Goals 7 and 13 initiatives are vital to curbing energy poverty, deforestation, and forest degradation and increasing energy efficiency.

Currently, over 40% of people in Nigeria do not have access to electricity and rely on traditional biomass - wood, agricultural residues, and dung - for cooking and heating. Better access to a sustainable energy supply is necessary for economic growth, business development, and income-generating activities. Homes, schools, and health centers need adequate lighting, communication, water supply, and heating and cooling energy. Streetlights improve safety at night. Better fuels and cooking stoves are necessary to end the exposure of women and children to indoor air pollution and reduce the daily work of collecting wood. Added to it is the increasing high population with a series of barriers to energy access. The increasing high population can become more challenging.

Nigeria, whose overall electrification rate is about 60%, expects an additional 20% to 30% of its population to have assessed electricity by 2030. However, in Nigeria's housing, with the population's expected growth by 2030, the housing infrastructure needs gap will be 50% higher, correlating to higher energy demand. By 2030 the overall energy demand in Nigeria is expected to more than double. The National Population Commission reports 200.2 million people in the country, and an electricity supply of 5,000 MW is grossly inadequate for many Nigerians. The nation's socio-economic growth requires much more than 5,000 MW of electricity. Energy planning experts using modern energy modeling tools estimate that for the Nigerian economy to grow 10 percent, the country’s electricity requirement by 2020 will be 30,000 MW by 2030. it will be 78,000 MW (Chika Izuora 2018). With the increasing need for energy and reliance on imports, an unbalanced mix of energy sources, there is a need to slow down energy consumption and increase energy efficiency.

Nigeria spends an increasing share of its GDP on energy imports, with devastating effects on economic growth and levels of indebtedness (subsidies). Energy efficiency and greater use of renewable sources can thus reduce dependence on imported energy and contribute to economic stability and environmental sustainability. Nigeria has been an energy importer and exporter, importing finished products and exporting raw products.

Nigeria's challenges include globalization, urbanization, technological innovation, fundamental economic and political power shifts, global environmental impacts, climate change, and potentially explosive social conflicts. Where any of the challenges have been net negative, energy's role has come into focus. These negative challenges encompass concerns about water security, food shortages, climate change, and the country's slower-than-expected performance of the SDGs. Adequate, available, and sustainable energy supply can provide a positive outcome for development and human well-being (portable water, food, health, and reduce other developmental challenges). Again, it could reduce the adverse effects that Nigeria has been experiencing (climate change, air pollution, lack of competitiveness, and inequality). The paradox of energy use is that it can simultaneously alleviate or aggravate all challenges. Energy is important for delivering health services but also causes health problems; it is necessary for delivering water and improving its quality, but it is also an important consumer and polluter of water. In most cases, if one was to drill down, energy aggravates the inequities in the world through the costs and benefits of its use (Tahir & Kanwal 2017).

The energy shortage in Nigeria has grown over the years to about 75% (International Energy Agency, 2020). Overdependence on fuel wood has led to deforestation, attendant degradation of the environment, and worsening desertification (Olure-Bank et al., 2019). An average annual deforestation rate of 2.38% between 2000 and 2020 in Nigeria is due in part to hikes in kerosene and cooking gas prices. Other alternative energy sources, including solar, wind, and wave, are largely underdeveloped in the country. Furthermore, as a result, domestic fuel prices have gone up several times with an attendant upsurge in transport fares and prices of goods and services. Nigeria, a developing country, has had a major focus on the GDP growth rate since its independence. But in recent years, the country has experienced one of its worst recessions, one of the reasons being a severe crisis in the energy sector. Nigeria's energy shortage is led by several reasons: isolated technology and 80% dependency on oil and gas income. Nigeria, developmental take-off should be based on its readiness to ensure an adequate and regular energy supply, which represents a crucial factor that supports industry and, thus, economic growth.

With the above challenges in mind, we need to re-examine the causal relationship between energy efficiency, CO2 emission, and GDP growth in the short and long run to better understand economic development's sustainability in the wake of unsustainable energy supply. It is also of note that Nigeria's economy has changed its structure during the past few decades. In particular, the share of agriculture to GDP has declined from about 56% in 1959-60 to 25% in 2015-16, and the share of services has increased from 38% to 58% during the same period. It would be interesting also to draw implications of this changing structure of the economy for energy efficiency

Therefore, the study's main objective is to answer three questions. First, is there a causal relationship between energy intensity (efficiency), CO2 emission, and GDP? If there is, what is the direction of the causal relationship between energy intensity and GDP in the short and long run? Finally, how is energy intensity expected to change in light of changing shares of the major economic sectors to GDP? This study uses energy intensity as a proxy for energy efficiency. Energy intensity is often used as a proxy for the energy efficiency of an economy (Poveda & Martinez, 2011), cited in Olure-Bank et al., 2019. High energy intensity implies low energy efficiency. This study, therefore, becomes imperative in analyzing the challenges of energy supply and examining the level of energy-induced growth in the Nigerian economy.

Most study uses energy intensity as a proxy for the energy efficiency of an economy. Energy intensity is energy use per unit of GDP, the total energy used for economic and social activity (Olure-Bank et al., 2019). The more intense the energy use, the higher the cost of converting raw material into the final product, resulting in meager economic performance, deteriorated environment, and low living standards. Energy consumption and economic growth have four hypotheses: growth hypothesis, feedback hypothesis, conservation hypothesis, and neutrality hypothesis (Yildirim et al., 2014).

Previous studies identify four different approaches to abstain if energy consumption reduces or increases with energy efficiency. (Reinhard & Alcot 2006) cited Olure-Bank et al., 2019. Firstly, Jevons (1865) states that without the efficiency increases in steam engines and metal smelting, the demand for coal could never have reached mid-19th-century high levels. Rosenberg sums up this argument for the backfire as follows: The Bessemer process was one of the most fuel-saving innovations in the history of metallurgy. Since innovation made it possible to use steel in various uses that were not feasible before Bessemer, and large increases in the steel demand. The Bessemer process reduces fuel requirements per unit of output (ratio). Still, its ultimate effect (from an economic view, not just an engineering perspective] was to increase, not reduce, demand for fuel. Notably, the efficiency improvements in finding energy are known as the energy return on investment (EROI). The increases come with the law of diminishing returns – deep mines and drill holes would have rendered energy more expensive rather than cheaper. Related to the gradual improvement of technology over time are the two phenomena 'lock-in' and 'path-dependency' (David 1986, Arthur 1989). Both explain, in part, the general issue of inertia imposed on the turnover of the capital stock. Note, however, that the replacement rate is usually not part of the discussion about the size of rebound effects since the two relevant measures for the assessment change in the technical efficiency with which particular goods and/or services are provided and total consumption levels.

Secondly, in the microeconomic approach of prices, substitution, and income effects, studies investigated direct rebound (additional demand for a good or service that can be more efficiently produced with the new technology). That is, buying an energy-efficient automobile, do people either buy or keep additional cars and does the weight of the household's entire car fleet perhaps increase (de Haan et al. 2006)? One could also ask whether a more energy-efficient car is driven more than non-energy-efficient cars (Greene 1992). Studies in the U.K. attest, for instance, that after a house is insulated or obtains a more efficient space heating system, people tend to heat more (Defra 2002). A useful survey of such direct rebound studies can be found in Greening et al. (2000). Of note, a reduction in the cost of energy service from energy efficiency can increase important bearing on the marginal consumer by making unaffordable energy service now affordable.

The workability of the microeconomic approach needs to meet two conditions: First, the system boundaries of empirical studies must be expanded to a world scale; since many energy markets and emissions are international, and embedded energy and material are increasingly traded globally, country or OECD studies alone are insufficient (Greenhalgh 1990; Dahlström & Ekins 2006; Rhee & Chung 2006). Secondly, the measure of total rebound must be the goal, i.e., indirect and direct effects: the increased purchasing power can be used to purchase anything and be shared by people, not in the market. The rebound from more efficient automobiles cars can be demand for air travel. However, tracing indirect effects with the tools of microeconomics proves to be extremely difficult (Howarth 1997; Roy 2000). Moreover, estimates of total rebound vary wildly. For instance, U.K. 4CMR (2006) arrives at 26%, and Allan et al. (2006) is closer to 40%. For others, it is inversed (Jevons 1865; Giampietro & Mayumi 1998; Brookes 2000) whether a rebound is greater or less than unity and is not concluded.

Thirdly, statistically, it can be tested on an aggregate and over time that technological efficiency increases and influences the size of energy consumption and its growth. The long-term increase in energy consumption needs no documentation (Reijnders 1998). Jevons (1865) was the first writer to show that consumption increases accompanied large and obvious efficiency increases. He traced efficiency increases in steam engines and steel (or pig-iron) production and then compiled statistics on coal consumption. Greenhalgh (1990) shows engineering efficiency gains of over 20% for household appliances in Denmark between 1977 and 1986, alongside rising electricity consumption. Rudin (2000) also study U.S. energy use in commercial buildings (8% more efficient from 1979 to 1995) and cars (30% from 1967 to 1997). Smil (2003) likewise covers changes in energy efficiency and consumption (Clapp 1994). Herring (2006) maintains a causal relationship between lighting efficiency and electricity consumption.

Since correlation is not causality, an ideal metric for energy efficiency levels valid in different periods and countries is needed for rigorous hypothesis testing. However, the global nature of environmental problems (climate change) and the global nature of the market for fossil fuels, for rigorous assessment of rebound effects, world statistics are needed. Or the metrics defined by products, industries, or sectors whose efficiency change can be measured in percentages and averages for the whole world economy evaluated. One must decide between financial, utility or welfare, and physical metrics to measure both economic growth and output as the denominator in input-output efficiency. Using GDP as the metric means economic output divided by energy input, which has disadvantages. GDP does not measure all economic activities (unpaid work to bartered goods), resource depletion, and so-called ‘eco services’ where the true costs are not reflected in the price. Moreover, the prices of the goods that influence GDP also count not on changes in efficiency and production costs but rather on consumer tastes, quality changes, and even politics (Schipper & Meyers 1992; Saunders 2000; Smil 2003).

For human utility, the measure of energy inputs also has problems. When a second person rides in a car, utility is doubled while energy input is the same, which is not technological efficiency change, but economy-wide energy efficiency. Welfare, too, is subject to many influences. The energy efficiency policies accessed involved energy inputs relating to physical and environmental relevant output. Finding a physical metric has proven difficult. Ayres & Warr (2005) state an exergy/energy ratio, i.e., Using useful energy for useful work, and work is defined by energy. How can one distinguish between an input and an output Joule of exergy? And since exergy is the energy of higher quality or greater availability to do work, what are the inputs into the process increasing this ‘quality’, or is it meant to describe, for instance, low-entropy coal and gas as opposed to dispersed energy closer to equilibrium?

Instead of energy or work, can the weight (or mass) of consumable and durable goods, including the (energy-using) stock of capital goods doing the work, serve as an aggregate metric? Radetzki & Tilton (2021) consider this, but qualitative product differences make it necessary to ‘weigh’ these weights. Dahlström & Ekins (2006) attempt to weigh physical characteristics – e.g., chemical elements, weight, waste, shape, and recycled tonnage – by economic value, attempting to integrate traditional material flow analysis with ‘value chain analysis. But here, the danger of conflating physical and subjective economic characteristics is great (Weisz et al. 2006). The quest for an all-encompassing, purely physical efficiency measure is a precondition for rigorous statistical analysis.

Another element ignored in studies is the size of energy rebound effects in time. Very well, there is an economic value when goods or services are produced in less time. Producing goods with the same amount of energy in a shorter time has additional value. Most rebound assessments remain silent about this time value of energy (work overtime equals power) and only address work over energy. The same argument can be put forward for energy considerations.

Lastly, early economic growth theories add technical change as an exogenous factor (Solow 1956). As a driver of economic growth, energy efficiency is part of the technological progress in neo-classical growth theory. With the increasing use of energy and other resources, environmental degradation is not seen as a significant barrier to economic growth. There will be more abundant substitutes (natural resources or human-made capital). In the 1990s, endogenous growth includes concerns about environmental and resource factors limiting growth in standard growth models (André & Smulders, 2006; Smulders & de Nooij, 2004). Endogenous growth theory gives new relationships between resource scarcity, technical change, and economic growth, and hence improvement compares to standard neoclassical growth theory. Endogenous growth includes rebound effects and diminishing returns to the ability of technology to reduce the amount of human-made and natural capital needed to produce resources. Technical change can offset diminishing returns by more productive and less resource-dependent technologies or by using less scarce resources. Microeconomics ignores substitution's macroeconomic and global effects. Thus underestimating thermodynamic limits, complementarity, irreversibility, waste, and scale (impact of trade) (Stern & Cleveland 2004).

Therefore, studies have no established relationship between energy efficiency and economic growth. Their development, methods used, and time frame analyzed differ. But, studies reveal four hypotheses tested and the result obtained. The first, non-causal hypothesis states no significant relationship exists between energy efficiency CO2 and economic growth, with real GDP growth from the service sector (low energy consumption). Therefore, proving the hypothesis means reducing energy consumption to decrease input cost and co2 emission, negatively affecting domestic output. The second, unidirectional causal hypothesis states real GDP growth is a function of energy consumption. If energy consumption is reduced, it will only lead to a marginal impact on economic growth. The conservation hypothesis is analyzed in the context of economic activity leading to more energy consumption. Economic activity leads to reduced energy consumption with a policy on the use of resources and reduced demand for products with low energy efficiency.

The third, unidirectional growth hypothesis states that energy efficiency significantly impacts economic growth. Meaning the relationship between these variables will negatively impact domestic output. But, the economic reality is that sometimes a negative relationship between energy efficiency and real GDP growth can differ depending on the exogenous variable change. Thus, energy efficiency increases output if an economy is more of a service sector with reduced energy consumption. On the other hand, low energy efficiency has a negative impact on the GDP if an economy relies on manufacturing with high energy intensity and low energy efficiency. The fourth, feedback hypothesis state that energy efficiency and economic growth dependent on each other. When energy efficiency increases, it leads to an increase in real GDP, thus, positively impacting energy consumption nationwide. Environmental policies will generate both energy consumption and a GDP decrease, and energy efficiency will lead to GDP growth and an increase in energy consumption.

The first strand of works on the nexus between energy efficiency, carbon emission, and economic growth focused on environmental pollutants and economic growth nexus and related to the validity of the Environmental Kuznets Curve (EKC) hypothesis of the U-shaped relationship between per capita income and environmental degradation in the long run (Akbostanci, Turut-Asik & Tunc, 2009; Xinshen et al., 2009 and He & Richard, 2010). Another strand relates to energy consumption and economic growth nexus (Mehrara, 2007; Olusegun, 2008; Akinlo, 2009; Esso, 2010; Fatai, et al. 2004; Sa'ad, 2010; Apergis & Danuletu, 2012; Kemisola, et al. 2014; Olure-Bank, et al. 2019).

So, to ensure appropriate recovery of the socio-economic process of Nigeria within the framework of the effective economic system, development, enhancing structures, patterns, and evolution of production, allocation, and utilization of its vast resources, similarly ensuring optimal development and efficient management of available resources, equitable allocation of such resources and effective utilization to achieve economic development ultimately, the issue oil production, carbon emission to gas flaring on economic growth in Nigeria. This study takes the first strand of works on the nexus between energy efficiency, carbon emission, and economic growth focused on environmental pollutants and economic growth nexus and related to the validity of the Environmental Kuznets Curve (EKC) hypothesis of the U-shaped relationship. Methodology of the form of Granger causality and regression model to examine the dynamic effect of oil production. Carbon emission from gas flaring on economic growth in Nigeria, again, interdependence variance auto-regression (VAR) is used to establish the economic growth response of external and internal carbon emission.

METHODS

This study combines the two methods within the Autoregressive Distributed Lag (ARDL) bounds testing framework and the Granger causality test. The central issue in the causal relationship between economic growth and energy consumption has been whether economic growth stimulates energy consumption or is a stimulus for economic growth via indirect channels of effective aggregate demand, improved overall efficiency, and technological progress (Ghosh & Basu, 2006). There are two related hypotheses on the nexus between energy consumption and economic growth: the energy-led growth and growth-led-energy hypotheses. The two hypotheses are established in development studies, with inconsistent and controversial outcomes due to various structural frameworks and policies from countries, periods, methodology, various energy consumption and growth proxies, omitted variables, and varying energy consumption patterns. To capture the causality relationship between oil price, energy consumption, investment, and real economic growth and to account for possible feedback effects from the short-run fluctuations to the long-run steady state of the relationship between the key variables. The model is expressed in the form that allows for testing both unit root and co-integration. Mathematically:

$$RGDP = f\,(OLP, CEGF, OLC, INVEST) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Mathematically log expressed for hypothesis formulation:

$$InRGDP_t = \alpha_0 + \beta_4 OLP_t + \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$InRGDP_t = \alpha_0 + \beta_1\, InCEGF_t + \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$InRGDP_t = \alpha_0 + \beta_1 OLP_t + \beta_2 InCEGF_t + \beta_3 OLC_t + \beta_4 INVEST_t + \mu \quad \ldots\ldots..(4)$$

Where; RGDP = Real gross domestic product proxy by Oil production; CEGF = Carbon emission from gas flaring proxy by Oil consumption; INVEST = Investment; OLC = Crude oil production growth rate α_0 = Intercept; $\beta_{1\text{-}4}$ = Slope or regression parameters; and μ = Stochastic term.

The model revealed that the first and second lag of RGDP growth rate [DRG(-1) & DRG(-2)]; change in crude oil production growth rate (DOLPG), first and second lag of crude oil production growth rate [DOLPG(-1) & DOLPG(-2)]; change in crude oil consumption growth rate (DOLCG), first lag of crude oil consumption growth rate DOLCG(-1), change in the growth rate of carbon monoxide emission from gas flaring (DCO2G), first and second lag of growth rate of carbon monoxide emission from gas flaring [DCO2G(-1) & DCO2(- 2)] and change in investment growth rate (DINVTG), first and second lag of investment growth rate [DINVTG(-1) & DINVTG(-2)] are the only significant factors influencing economic growth proxy by the change in RGDP growth rate (DRG). Therefore, this study rejects the null hypotheses and concludes a causal relationship between oil production, carbon emission from gas flaring, and economic growth in Nigeria during the study period.

The econometric analysis of the relationship among energy consumption, carbon emission, and growth rate in Nigeria uses data from 1980 to 2021. The period for the analysis is chosen based on the availability of data from various sources. The data sourced are from Central Bank of Nigeria Statistical Bulletin, Volume 22, 2021; World Development Index, 2022 and International Energy Agency (IEA) publications for 42 years (1980 – 2021). The model designed for the study is a multiple regression equation. The model predicts the relationship between the dependent variable (RGDP) and independent variables ("OLP", "CEGF", "OLC" and "INVEST"). The study adopts a dynamic methodology of Granger causality and dynamic regression model to examine the dynamic effect of oil production and carbon emission from gas flaring on economic growth in Nigeria and further use the two-step granger co-integration test framework to establish the economic growth response of external and internal carbon emission which serves as the methodological rationale for the study

RESULT AND DISCUSSION

Table 1 reveals descriptive statistics of the variables. The average values of the variables are close to their median values denoting the balancing point of the data. The volatility is represented by the standard deviation values and how the information is spread around its mean. In agreement with Dantama et al. (2012). the skewness ranges from 2 to þ2, while the values of Kurosis come in between 7 to þ7. The statistical values of skewness and Kurtosis depict the data as symmetrical and normally skewed with normal distribution. Additionally, the Jarque-Bera test also affirms the normal distribution. The probability values of all the variables further prove that the information's significance is proportional and symmetrical.

Table 1. Descriptive statistics and normality check.

	RGDP	OLP	CEGF	OLC	INVEST
Mean	11.47679	1.196004	11.37112	11.48075	11.70743
Median	11.47722	1.44857	11.37501	11.47334	11.74016
Maximum	12.21427	1.948165	12.02514	12.19126	12.80323
Minimum	10.56636	0.35714	10.60202	10.68293	10.08623
Std. Dev.	0.365443	0.647826	0.341628	0.358035	0.529208
Skewness	-0.033495	-0.913301	-0.02021	0.00077	-0.31749
Kurtosis	2.367933	2.638812	2.267537	2.285484	3.196525
Jarque-Bera	5.740122	49.25928	7.646017	7.253849	6.277666
Probability	0.056695	0. 000000	0.021862	0.026598	0.043333

The first step is to know the order integration of the variables as time series data are not stable and to know the best integration method to use test. The ADF unit-root test is used, and variables are not stationary at level. The log difference of the variables is then examined, and the estimated results are revealed in Table 2. The test result reveals the time series variables; change of real gross domestic product growth rate (Δrg), change of crude oil production growth rate (Δolpg), change of crude oil consumption (Δolcg), change in the growth rate of Carbon Monoxide Emission from Gas Flaring (Δ 02gC), and change in investment growth rate (Δinvtg) are all stationary at order one (I(I). In contrast to the Ogundipe et al., (2019) unit root analysis results, the variables are stationary at their levels. In this study, all the variables become stationary at their first difference a common order of integration I(1). These findings imply that the variables converge to their mean values. Thus, the stationarity properties of the variables nullify the possibility of estimating spurious estimates from the regression analysis

Table 2: Unit root test

Variables	ADF Tau Statistics		Order of Integration
	Intercept	Linear Trend	
Δrg	-7.7438*(1) [-3.6156]	-7.6760*(1) [-4.2191]	1
Δolpg	-5.7002*(3) [-3.6268]	-5.6156*(3) [-4.2350]	1
Δolcg	-5.1342*(4) [-5.1342]	-4.9951*(4) [-4.2436]	1
ΔCO2g	-8.6359*(0) [-3.6105]	-8.5399*(0) [-4.2119]	1
Δinvtg	-9.7901*(0) [-3.6145]	-9.6422*(0) [-4.2119]	1

Note: * significant at 1%; Mackinnon critical values are shown in parenthesis. The lagged numbers shown in brackets are selected using the minimum Schwarz and Akaike Information criteria

Next, the co-integration test and the results of the long-run OLS model are in Table 3 and Table 4.

Table 3. Co-integration test results

Null Hypothesis: No Co-integration (Intercept Model)			
Exogenous: Constant and Lag Length: 0 (Automatic - based on SIC, maxlag=9)			
	t-statistic		Prob*
Augmented Dickey-Fuller test statistic	-5.802866		0
Test critical values:	1% level		-3.62678
	5% level		-2.94584
	10% level		-2.611531
*MacKinnon one-sided p-values			
Pairwise Granger Causality Tests			
Null Hypothesis:	Obs	F-Statistic	Prob
DOLPG does not Granger Cause DRG	39	0.58844	0.448
DRG does not Granger Cause DOLPG		0.03927	0.844
DOLCG does not Granger Cause DRG	39	0.75605	0.3903
DRG does not Granger Cause DOLCG		0.21198	0.648
DOLCG does not Granger Cause DRG	39	0.75605	0.3903
DRG does not Granger Cause DOLCG		0.21198	0.648
DINVTG does not Granger Cause DRG	39	3.55365	0.0675
DRG does not Granger Cause DINVTG		1.76833	0.192
DOLCG does not Granger Cause DOLPG	39	2.57916	0.117
DOLPG does not Granger Cause DOLCG		0.065	0.8002
DCO2G does not Granger Cause DOLPG	39	3.11579	0.086
DOLPG does not Granger Cause DCO2G		6.5036	0.0152
DINVTG does not Granger Cause DOLPG	39	0.20215	0.6557
DOLPG does not Granger Cause DINVTG		0.03696	0.8486
DCO2G does not Granger Cause DOLCG	39	0.9185	0.3443
DOLCG does not Granger Cause DCO2G		0.01032	0.9197
DINVTG does not Granger Cause DOLCG	39	3.29949	0.0776
DOLCG does not Granger Cause DINVTG		0.79254	0.3792
DINVTG does not Granger Cause DCO2G	39	0.75206	0.3916
DCO2G does not Granger Cause DINVTG		1.39954	0.2446

Table 4: Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob
C	-0.036	0.046	-0.789	0.439
DRG(-1)	-0.691	0.164	-4.216**	0
DRG(-2)	-0.436	0.179	-2.431*	0.024
DRG(-3)	-0.252	0.165	-1.524	0.143
DOLPG	-0.16	0.077	-2.086*	0.034
DOLPG(-1)	-0.617	0.297	-2.077*	0.04
DOLPG(-2)	-0.628	0.08	-7.801**	0
DOLCG	-0.114	0.053	-2.151	0.033
DOLCG(-1)	0.076	0.027	2.822*	0.016
DOLCG(-2)	0.326	0.68	-0.48	0.636
DCO2G	0.75	0.313	2.400*	0.025
DCO2G(-1)	0.443	0.157	2.822*	0.016
DCO2G(-2)	0.251	0.116	2.168	0.031
DINVTG	-0.006	0.003	-1.963*	0.05
DINVTG(-1)	-0.121	0.036	-3.332*	0.004
DINVTG(-2)	0.189	0.031	6.034**	0
R-squared	0.86251	S.D. dependent var		0.278124
Adjusted R-squared	0.818589	F-statistic		22.1221
Durbin-Watson stat	1.824953	Prob(F-statistic)		0.005569

The estimated long-run model rejects the null hypothesis "no stationary, " implying that "no co-integration" is rejected for intercept and linear deterministic models at 1% McKinnon critical value as revealed in Table 3. This implies that there is a long-run relationship between a change in real gross domestic product growth rate (Δrg), a 1% increase in the real growth of GDP will decrease the growth of energy intensity by 0.19% in the long run, and a change of crude oil production growth rate (Δolpg), change of crude oil consumption (Δolcg), change in the growth rate of Carbon Monoxide Emission from Gas Flaring (Δ 02gC), and change in investment growth rate (Δinvtg) in Nigeria between 1980 and 2021. This suggests that economic growth has a negative influence on environmental quality. Co-integration shows that causality exists at least in one direction. These results are consistent with those obtained in an earlier study by Opeyemi (2017) for Africa. This supports the conservation hypothesis focusing mainly on electricity consumption rather than all forms of energy. The results also agree with the findings of Huang et al. (2008) for poor countries. In long-run dynamics, the coefficient of the EC term is statistically significant with a negative sign in equations 2(a) and 2(b). This implies that a change in GDP is expected to affect the energy intensity through feedback in agreement with Olure-Bank et al. (2019).

The findings of this study also support the findings of other previous studies such as Zhihui et al. (2022), Akadiri & Adebayo (2021), Hu et al. (2021), He et al. (2021), Dantama et al. (2012), Petrovic-Randelovic et al. (2020), and Muhammad & Jelilov (2015). Zhihui et al. (2022) investigate the influence of economic growth, energy consumption, renewable electricity output, and energy efficiency on energy-related emissions. The results reveal economic growth and energy consumption significantly increase energy-related emissions. Conversely, renewable electricity and energy efficiency are significant tools for lowering energy-related emissions in the region. Again, a unidirectional causality is revealed from energy consumption and renewable electricity output to energy-driven emissions. However, an inverse effect is revealed between economic growth, energy efficiency, and energy-driven emissions. From findings, this study states the increasing need for renewable electricity output and the adoption of energy-efficient technologies to reduce environmental degradation and emission level.

Akadiri & Adebayo (2021) also analyzed the asymmetric association between economic growth and other energy, economic growth, and financial indicators in the case of India. The non-linear autoregressive distributed lags model demonstrates that economic growth, financial development, and non-renewable energy consumption promote environmental quality degradation, as renewable energy consumption promotes environmental quality.

Hu et al. (2021) reveal the existence of bidirectional causal nexus between renewable energy use and CO2 emissions and a unidirectional causal nexus between CO2 emissions and economic growth. The study of Petrovic-Randelovic et al. (2020) asserted the existence of bidirectional causal nexus between energy consumption and CO2 emissions while a unidirectional causal association between CO2 emissions and economic growth. Energy consumption and technical innovation lead to higher economic growth at the cost of environmental degradation.

He et al. (2021) explore the path of carbon emissions reduction in China's industrial sector through energy efficiency enhancement induced by R&D investment. The increasing incidence of power shortages has been identified as responsible for increased CO2 emissions and dwindling economic development in most underdeveloped countries. This is not unconnected with the inability to develop new generating capacity as hydropower has been the only power source, thereby diminishing electricity supply severely during droughts.

Dantama et al. (2012) examine the impact of energy consumption and economic growth in Nigeria from 1980-2010. The results indicate a long-run relationship between economic growth and energy consumption variables exists. Petroleum and electricity consumption is statistically significant on economic growth, but coal consumption is statistically insignificant. Also, the speed of adjustment in the estimated model is relatively high and contains the expected significant and negative signs. In a recent study, Muhammad & Jelilov (2015) revered that there exists a co-integration relationship between energy consumption and economic growth. Though they have fluctuating relationships in the short term, in the long run, energy consumption and economic growth have a long-term stable equilibrium relationship. The Granger causality test shows that GDP is the Granger cause of energy consumption, and an increase in Nigeria's GDP directly leads to an increase in energy consumption. Therefore, a decline in GDP has had an adverse effect on energy consumption in Nigeria.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study examines the causal effect of oil production and carbon emission from gas flaring on the economic growth of Nigeria from 1980-2021. The results reveal that economic growth and energy consumption significantly increase energy-related emissions. Increased income level influences investors and industrialists to invest in the industrial sector, enhancing production, diversification, and expansion. Of note, increased production and expansion of industries increase energy demand. Energy demand met by consuming fossil fuel increases energy-related emissions in Nigeria and negatively affects environmental quality. More importantly, carbon emission impedes environmental sustainability and sustainable economic growth in Nigeria.

Again, oil production and carbon emissions negatively affect Nigerian economic growth. Theoretically, high energy consumption by the industrial sector is an important economic growth driver, increasing energy-related CO2 emissions. The significance of the income from oil production is yet to impact citizens in the case of Nigeria. Since Nigeria's economies focus on developing its economy, the industrial sector is considered key for diversification, high-income level, and economic growth. There is a need for more energy consumption from the industrial sector to increase productivity and, thus, income. The increased income level will further promote non-renewable energy use, which is not harmful to environmental quality. On the other hand, the study reveals that renewable electricity output and energy efficiency could be measured for reducing harmful environmental quality. But, energy-related emissions are increasing, meaning renewable energy electricity output and energy efficiency are not up to the mark level in Nigeria.

Recommendations

Based on the findings, this study recommends that renewable energy electricity output and energy efficiency could be used for environmental recovery and sustainability. Since the industrial sector is the key sector that helps the economy to stabilize and achieve higher economic growth levels, policies must be made to accommodate the structural transformation of the industrial sector towards renewable energy resources. Such can include subsidies and tax benefits for industries using renewable energy to make renewable energy resources more attractive and feasible for the economy.

In addition, policies that target renewable electricity need more attention to attain a low-carbon economy in the future. Moreover, energy-efficient resources must be adopted and promoted to save energy, lower energy demand, and reduce energy-related emissions. Importantly, there is a need for increased investment in technologies and research and development to promote renewable energy and energy-efficient products and services usages.

The ultimate goal is to supply adequate energy to support the growth and development of the economy from viable sources and to have a one-stop shop that assesses what infrastructure is necessary for such to happen that can lead to industrial development. Note the country does not need to sacrifice economic growth for low emission levels. CO2 emissions reduction can be achieved via energy conservation without negative long-run effects on economic growth. So, the government needs to integrate emissions regulation with economic development policies.

This study's scope is limited to CO2 emissions from the industrial sector, oil production, and gas flaring. It does not account for electrification, fuel switching within the building sector, or transportation-related CO2 emissions.

The recommendations for future studies, keeping in view the future growths in various sectors of the economy, the economic policies maker of the country need studies for future projections on energy needs and use. This is important information for the timely development of the energy sector as there is a need to conduct a more detailed study to project for future energy requirements to be better informed for making credible plans for the energy sector's timely development of energy sector. There is a need to conduct a more detailed study to project future energy requirements to be better informed for making credible plans for the energy sector.

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