Revisiting the nexus between renewable energy consumption and economic growth in Nigeria: The VECM approach

Abstract

Theresearch investigates the effect of renewable energy consumption on economic growth as well as analyzing the dynamic relationship between both variables from 1990 to 2022. Annual secondarydatacoveringthe periodbetween 1990 and 2022 wereused in thestudy. Data on real gross domestic product, renewable energy consumption (% of total final energy consumption), gross capital formation (% of GDP), labor force, total and trade (% of GDP) were sourced from World Development Indicator. The study applies Johansen co-integration test andVector Error Correction Model (VECM) to examine the effect of renewable energy consumption on economic growth and other explanatory variables as well as using pairwise granger causality test to examine the causal relationship between both variables. The empirical evidence revealed long-term relationship between renewable energy consumption and economic growth. Evidence shows that there is no causality either unidirectional or bi-directional between both variables. In short run,renewable energy consumption revealed a significant positive impact on economic growth. This shows that renewable energy may stimulate economic growth, particularly as it has a greater short-term impact on economic growth than capital formation.The key policy implication drawn from the results indicate the need for investment in renewable energy technologies and infrastructure, which can help to increase the availability and affordability of renewable energy, improve workforce development in Nigeria renewable energy sector.

Keywords: renewable energy consumption, economic growth, VECM model, capital formation, causality, Nigeria

1. INTRODUCTION

The Paris Climate Change Agreement (UNFCCC) and the 2030 Agenda for Sustainable Development (SDGs) both depend heavily on energy in achieving their respective goals for human preservation. Numerous nations are looking for sustainable and renewable energy supply alternatives because of things like rising energy demand, depleting fossil fuel reserves, lowering CO2 levels, and global climate change (Abanda 2012; Alloisio*et al.*, 2022; Kuamoah 2020). These efforts are crucial for human preservation and align with the objectives of the Paris Agreement and the SDGs. The transition to clean energy sources, such as solar, wind, geothermal, and biofuels, is essential for achieving these goals (Davide *et al.*, 2019). However, it is important to consider the potential challenges and threats, such as extreme weather conditions, natural disasters, and cyber threats that may arise during this energy transformation (OECD 2022). By promoting international cooperation and adopting a holistic approach, we can create a green and clean energy sector that contributes to sustainable development and addresses the climate-energy nexus (Overland *et al.*, 2021).

According to Egbetokun*et al.,* (2020), the potential for using renewable energy sources as part of the next industrial revolution is very promising and contributed positively to economic growth in many nations. Economically speaking, no country on earth has a clear advantage over another when it comes to renewable energy sources. The high cost of the technologies compared to fossil fuels has historically been a major barrier to the exploitation and consumption of renewable energy sources (Chanchangi*et al.,* 2021; Gershon & Nwokocha 2017). However, it is a known fact that fossil fuels are harmful to the environment, are not renewable, and are no longer sustainable. This made the process of moving away from fossil fuels and redesigning entire systems to utilize low-carbon energy sources which is known as the energy transition more important. Energy transitions have shaped industrial civilization throughout its history. In less developed agrarian economies Nigerian inclusive, simple forms of agriculturehave been used to harness solar energy for basic caloric needs and other essential requirement (Tian*et al*., 2022; Timmons et al 2014). As economies grew, the reliance on firewood and biomass energy became insufficient, leading to the adoption of hydropower, coal, and eventually oil and natural gas as energy sources (Alao-OwunnaandAdediwura, 2023; Edomah, 2019; Fischer-Kowalski, *et al.*, 2019).

The distinctive energy transition from one major fuel source to another is a significant shift that is currently taking place in response to concerns about the environment, supply restrictions, price increases, and technological advancements (Kabir, *et al.*, 2022; Tahvonen&Salo, 2001; Wang *et al.*, 2022). “Fossil fuels like coal, oil, and natural gas are currently the primary drivers of both the growth in energy production in developing economies Nigeria inclusive, as well as their dominance in industrial economies” (Thompson &Zakhirova, 2017). Countries are attempting to transition away from fossil fuels and toward renewable energies, but this will take time. To cut carbon emissions and keep global warming under control, deliberate decisions and consistent policymaking are needed. By safeguarding the environment, resources, and the environment, increased reliance on renewable energy would contribute to environmental sustainability. The factors that contribute to the low use of renewable energy may include large initial outlays which are related to the purchase of alternative fuels Ciołek*et al.,*(2022). Furthermore, in order to deliver energy to consumers from sources like wind, water, sunlight, biomass, and geothermal energy, updated, modern, and efficient electricity grids are needed (Haseeb *et al.,* 2019,Olabisi, *et al.,* 2019; Kayani 2021).

As emphasized by Azeakpono and Lloyd (2020) energy is a crucial enabler that has an impact on a variety of aspects of human and economic development. "Without sufficient energy capacity and affordable modern energy services, economic growth and development may be limited. Energy access was frequently a problem in developing countries in general, and specifically in Nigeria, as evidenced by the fact that more than two-thirds of Africans do not have access to electricity. Modern energy services have been a prerequisite to sustained development in every advanced economy" (Heubaumand Biermann 2015)."Untapped renewable energy sources like solar, hydroelectric, wind in coastal areas, and geothermal in the north are abundant in Nigeria, which is encouraging. However, the increasing emphasis on renewable energy is driven by the need to mitigate climate change and promote sustainable development" (Rubio & Folchi, 2012). "Renewable energy sources, such as wind, solar, and hydroelectric power, have been found to contribute more to economic growth"(Alao-Owunna, *et al.,* 2021; Armeanu*et al.*, 2019; Armeanu, 2017;Ayoade*et al.*, 2023;Bușu, 2018; Okedu, 2018; Ohler & Fetters, 2014; Sabiri *et al.*, 2014; Shahbaz *et al.*, 2020; Yikun, 2021) and have a significant inverse relationship with carbon emissions (Sharif *et al.,* 2021;Thombs, 2018; Yuan *et al.,* 2022; Zhang *et al.*, 2021; Vo *et al.*, 2020). The transition to renewable energy is crucial for the welfare of economies and the global response to climate change.

Also, it can be deduced from the reviewed literatures that the topic of renewable energy and economic growth has been studied from different perspectives ranging from the study of Masih and Masih (1996) , Cheng (1999) , Apergis and Payne (2010), Ozturk et al. (2012), Ouedraogo (2013) Aslan et al. (2014), Kasman and Duman (2015) Costantini and Martini (2010), Belke et al. (2011), Coers and Sanders (2013, Menyah and Wolde-Rufael (2010) for USA, Kahsai et al. (2012), Śmiech and Papież (2014), Apergis and Danuletiu (2014) Jafari et al. (2012) for indonesia, Dogan (2014),Nasreen and Anwar (2014), Tugcu c,. & Alper A. (2012), Dogan et al. (2016), Haseeb et al., 2019, Azeakpono& Lloyd (2020) for Nigeria , Kayani 2021 for United Arab Emirate to Azeakpono and Lloyd (2022). However, only few of the above are country specific while it also shows that there is no consensus among the empirical literatures reviewed on the effect, the direction of the relationship and causality between renewable energy and economic growth both in the short-run and long –run.

Additionally, as indicated by Apergis and Danuletiu (2014), Azeakpono and Lloyd (2020), prior research on the nature of the relationship between renewable energy and economic growth has been inconclusive, as majority of studies reviewed do not show that energy consumption has long-term effects on overall economic growth and there aren't many impartial analyses of the Nigerian case in terms of growth. Therefore, given the arguments above; this study seeks to contribute to the existing body of knowledge on the topic by conducting a study on Nigeria and to also examine the effect of renewable energy consumption on economic growth between 1990 and 2022. The rest of the paper is couched as follows:a review of empirical literature for developed and developing countries as well as Nigeria, followed by data and methodology, findings (results and discussion), conclusion and policy recommendations.

2. Literature Review

2.1 Evidence from Developed Countries

Soava et al. (2018) investigate "the causal link between economic growth and consumption of renewable energy across the 28 European Union member states. They highlight bidirectional or unidirectional Granger causalities between the two macroeconomic indicators for each country in the panel, using data from 1995 to 2015 to support their claim that the use of renewable energy has a positive impact on economic growth". In the same vein Bužinskienė (2019) also investigate "the impact of renewable energy development in Lithuania's energy economy using multiple linear regression models. They concluded that wind, sun, water, geothermal, and biomass are examples of renewable energy sources that can't always be used together because they compete with one another and lower the efficiency of the energy economy. To evaluate the effects of the energy economy on energy productivity and intensity, three combinations of renewable energy sources have been developed in this context. The efficiency of the energy economy has been found to be significantly impacted by the combination of resources".

Shahbaz *et al.*, (2020) investigate "the impact of the use of renewable energy on economic growth in 38 nations between 1990 and 2018. They used the heterogeneous non causality approach, fully modified ordinary least square (FMOLS), and dynamic ordinary least square (DOLS). They attest to the existence of a long-term connection between the use of renewable energy and economic expansion. Furthermore, the study also observed that consumption of renewable energy has a positive effect on economic growth for 58% of the sample countries, as well as for nonrenewable energy, capital, and labor". Silva *et al.*, (2012) examine "the impact of renewable energy sources on economic growth and CO_2 emission using structural vector autoregressive (SVAR) approach between 1960 and 2004. They concluded that all countries sampled except for USA have an increasing renewable energy share at economic costs in terms of GDP per capita. There was also an evident of decrease CO2 emissions per capita". Bhattacharya et al. (2016) also investigate "the effects of renewable energy consumption on economic growth between 1991 and 2012 in 38 of the top countries that use renewable energy. They discovered that there are long-run dynamics between economic growth and conventional energy-related inputs using panel estimation techniques".

In 2015 study, Rafindadi and Ozturk examine “whether Germany's economic growth between 1971's first quarter and 2013's fourth quarter was influenced by the use of renewable energy. The study used the Bayer-Hanck combined cointegration test, the ARDL bounds testing approach to cointegration, and the Clemente Montanes-Reyes de-trended structural break test. Additionally, the VECM Granger causality framework was used to observe the causality analysis. They came to the conclusion that Germany's consumption of renewable energy supports the nation's economic expansion”. In a similar vein of one country analysis, Yildirim and Can (2017) use “the VAR analysis for 1960 to 2013 to examine the effects of renewable energy on economic growth in Turkey. They concluded that renewable energy does not significantly affect real output, but they also found that a rise in the production of renewable energy has led to a decrease in the CO2 rate”. While Kahia et al., (2021) use “the simultaneous equation modeling approach to look at a potential relationship between economic growth, green energy, and environmental quality in the case of Saudi Arabia over the years 1990-2016. In addition to confirming the conservation hypothesis and the bidirectional relationships between economic growth and CO2 emissions and between CO2 emissions and renewable energy consumption, they discovered that economic growth has a unidirectional causal impact on the consumption of renewable energy”.

2.2 Evidence from Developing Countries

Namahoro*et al.,* (2021) examine “the effects of economicgowth, population, and renewable energy growth on CO2 emissions in the east African region using data from 1980 to 2016 from common correlated effect means group and asymmetric analysis. Utilising causality tests, nonlinear autoregressive distributed lagged (NARDL), and common correlated effect means group (CCEMG). They come to the conclusion that while the use of renewable energy has a negative impact on regional CO2 emissions, economic and population growth have a positive impact. The correlations between CO2 emissions and their determinants (economic growth, population expansion, and renewable energy) are both symmetric and asymmetric, and they vary greatly by country. The study's causality hypotheses vary depending on the nation and the region. This study also illustrates the relationship between the growths of renewable energy, wherein regional economic growth is positively impacted by renewable energy”.

The economic growth hypothesis and renewable energy is examined by Xie *et al.*, (2022) using data from the following 11 countries from 1990 to 2020. The study confirms the validity of the renewable energy led growth hypothesis using a nonparametric panel data approach. Additionally, it has been discovered that these economies' trade openness, gross domestic product, and industry value added all positively influence economic growth. Two-way causal association between the variables is exist as indicated by the panel causality test. Similar to the above, Sasana and Ghozali (2017), looks at how consumption of fossil and renewable energy affects economic growth in South Africa, Brazil, Russia, India, and other countries. They utilize panel data from 1995 to 2014 along with multiple linear regression using the fixed effect model method. The findings demonstrated that consumption of fossil fuels, particularly coal, has a positive and significant impact on economic growth in the study countries.

In their investigation of the dynamic relationship between the use of renewable energy and trade performance in 42 SSA countries, Akinyemi *et al.,* (2019) also took into account "the mediating functions of regulation, regulatory quality, and private sector access to financing. The study discovered a link between the use of renewable energy and the trade performance indicators. However, they emphasize that there is potential for a net positive impact of using renewable energy on exports of manufactured goods with the reduction of corruption, improved regulatory framework, and better financing for the private sector. They discover that better regulatory frameworks and better financing for the private sector are crucial conditioning structures for renewable energy and the total trade nexus". Between 1990 and 2019, Salman and Hosny (2021) investigate "the relationship between Egypt's renewable energy resources and economic growth in order to achieve sustainable development goals. They discovered that one of the main forces behind the favorable and significant effects of electricity produced from renewable energy sources, CO2 emission, and exchange rate in Egypt on economic growth is government support using the autoregressive distributed lag model (ARDL). However, a difficult aspect of achieving sustainability is still the positive and significant impact of carbon dioxide".

2.3 Evidence from Nigeria

Using ARDL cointegration techniques and the Granger causality test, Azeakpono and Lloyd (2020) investigate "the impact of renewable energy consumption on economic growth as well as the direction of causality among the major variables. They came to the conclusion that renewable energy has a negligible adverse effect on economic growth, while emphasizing that there is no causal link between the variables". In a similar vein, Goshit and Shido-Ikwu (2022), using Autoregression Distribution Lag and Toda-Yamanoto(T-Y) causality approach, investigate the impact of renewable energy consumption on economic growth between 1990 and 2019. The outcome demonstrates that there is a short- and long-term negative but significant relationship between economic growth and renewable energy. While Maji (2015) used the Autoregressive Distribution Lag (ARDL) method to examine the question "does clean energy contribute to economic growth. He emphasizes that there is a significant, albeit unfavorable, correlation between clean energy indicators and economic growth over the long term. He goes on to say that although not significantly different from zero, a combination of negative and positive relationships between clean energy indicators and economic growth were found in the short term.

Umeji*et al.,* (2023) use "Toda-Yamamoto augmented granger causality test to test for the nature of the relationship between the two variables and Auto Regressive Distributive Lag (ARDL) bounds test examine the impact of renewable energy use on economic growth in Nigeria. The variables had a two-way link. Additionally, the regression findings demonstrated that the use of renewable energy significantly boosts economic growth". In the same vein Salami *et al.,* (2016) use "the generalized method of moment to estimate the relationship between energy consumption, financial development, and economic growth. The study affirms the inducement effect of the expansion of the financial sector on energy consumption while also suggesting that increased energy consumption will accelerate economic growth in Nigeria". *Fashayitan et* *al.*,(2022) also investigate “the effects of renewable energy consumption and financial development for 60 years, using Autoregressive Distribution Lag (ARDL). They indicated that financial sector intermediation had a significant positive and long-term effect on energy demand in the Nigerian economy”.

Using the Toda Yamamoto approach, Gershon and Emekalem (2021) look into “the factors that influence the consumption of renewable energy over a 24 year span, from 1990 to 2014. They came to the conclusion that real income and CO2 emissions are the two main factors influencing Nigeria's demand for imported oil products, while there is a long-term relationship between renewable energy consumption and its determinants. It was discovered that trade openness had little impact. The analysis also revealed that there is no causal relationship between some of the factors influencing the consumption of renewable energy. However, unidirectional causality links CO2 emissions to GDP, indicating that fossil fuels are important contributors to real GDP or Nigeria's economic growth.This study has found diverse empirical views on the debate surrounding the relationship between the renewable energy consumption and economic growth, after critically evaluating literatures for different categories of economies. It was noted that most studies in Nigeria specifically focus on examining only the effect of renewable energy consumption on economic growth but only few studies emphasize if the relationship between both variable is unidirectional or bidirectional in nature alongside the effect of renewable energy on economic growth in the Nigeria context”.

3. Data and Methodology

3.1 Sources of Data

The study is based on an empirical research methodology, and the analysis relies on the values of the variables. For this study, the researcher used secondary sources of data. The statistics cover thirty tthree years (32), from 1990 to 2022, and are taken from the World Development Indicators (WDI).

3.2 Definition and Measurement of Variables

Table 1: Definition and Measurement of Variables are presented in

Variable	Abbreviation	Measurement	Sources
Economic Growth	LNGDP	Gross Domestic Product	World Development Indicators
Renewable Energy Consumption	REC	renewable energy consumption (% of total final energy consumption)	World Development Indicator
Gross Capital Formation	GCF	Gross Capital Formation (% of GDP)	World Development Indicator
Total Labor Force	LNTLF	labor force, total	World Development Indicator
Trade	TO	Trade (% of GDP)	World Development

Openness	Indicator

3.3 Methodology

The theoretical bedrock of this study is the Solow growth model. This model was adopted to capture the relationship between renewable energy consumption which is referred to as technology in this study and economic growth in Nigeria. The rationale for this framework is to justify the inclusion of labour and capital as control variables. This research set out to examine the effect and the causal relationship between renewable energy consumption and economic growth in Nigeria. This relationship is designed on a linear regression model. An econometric model was built in line with the conceptual, theoretical, and empirical literature reviewed to capture the relationship between renewable energy consumption and economic growth in Nigeria and some variables were added to the model as control variables which have also been used by previous studies in explaining the effect of effect renewable energy consumption on economic growth (Azealpono& Lloyd 2020; Kayani 2021; Goshit&Shido-Ikwu 2022) and also to accomplish the objectives of this Study. The functional relation and the resulting model in the implicit form is:

$$GDP = f(REC, GCF, LNTLF, TO) \quad (1)$$

The model in equation (1) is specified explicitly as follows

$$lnGDP_t = \beta_0 + \beta_1 REC_t + \beta_2 GCF_t + \beta_3 LNTLF + \beta_4 TO_t + \mu_t \quad (2)$$

μ_t = Expression of errors.

While, β_1, β_2, β_3, and β_4 are parameters of the independent variables to be estimated in the course of this Study.

3.4 Estimation Techniques

The study adopted the Vector Error Correction Model (VECM). According to Granger and Engle (1987), “two or more non-stationary times series data are integrated together in a way that they cannot move away from some equilibrium in the long term. The two economists argued against the use of linear regression to analyze the relationship between several time series variables because de-trending would not solve the issue of spurious correlation. Instead, they recommended checking for cointegration of the non-stationary time series. They argued that two or more time series variables with I(1) trends could be cointegrated if it could be proved that there is a relationship between the variables. The decision criteria is reject at 5% level and also the null of no cointegration equation if the value of the trace and max statistics is greater than the 5% critical value, otherwise, fail to reject the null hypothesis”.

The error correction model (ECM), proposed by Engle and Granger (1987), and complements the cointegration regression model. Following Fan et al. (2017) and Shao et al. (2019b), the VEC model can be constructed as follows:

$$\Delta Y_t = \beta + \sum_{i=1}^{k-1} Y_i \Delta Y_{t-i} + \sum_{j=1}^{k-1} \delta_i \Delta X_{t-j} + \sum_{l=1}^{k-1} \varphi_i \Delta Z_{t-l} + \sum_{i=m}^{k-1} \varrho_i \Delta R_{t-m} + \sum_{i=n}^{k-1} \text{ɧ}_i \Delta T_{t-n} + \lambda ECT_{t-1} + \mu_t \quad (3)$$

However, the various models are displayed below;

$$\Delta LNGDP_t = \alpha_1 + \sum_{i=1}^{k-1} \beta_{11} \Delta GDP_{t-i} + \sum_{j=1}^{k-1} \beta_{12} \Delta REC_{t-j} + \sum_{l=1}^{k-1} \beta_{13} \Delta GCF_{t-l} + \sum_{i=m}^{k-1} \beta_{14} \Delta LNTLF_{t-m} + \sum_{i=n}^{k-1} \beta_{15} \Delta TO_{t-n} + \lambda ECT_{t-1} + \mu_{1t} \quad (4)$$

$$\Delta REC_t = \alpha_2 + \sum_{i=1}^{k-1} \beta_{21} \Delta GDP_{t-i} + \sum_{j=1}^{k-1} \beta_{22} \Delta REC_{t-j} + \sum_{l=1}^{k-1} \beta_{23} \Delta GCF_{t-l} + \sum_{i=m}^{k-1} \beta_{24} \Delta LNTLF_{t-m} + \sum_{i=n}^{k-1} \beta_{25} \Delta TO_{t-n} + \lambda ECT_{t-1} + \mu_{2t} \quad (5)$$

$$\Delta GCF_t = \alpha_3 + \sum_{i=1}^{k-1} \beta_{31} \Delta GDP_{t-i} + \sum_{j=1}^{k-1} \beta_{32} \Delta REC_{t-j} + \sum_{l=1}^{k-1} \beta_{33_l} \Delta GCF_{t-l} + \sum_{i=m}^{k-1} \beta_{34} \Delta LNTLF_{t-m} + \sum_{i=n}^{k-1} \beta_{35} \Delta TO_{t-n} + \lambda ECT_{t-1} + \mu_{3t} \quad (6)$$

$$\Delta LNTLF_t = \alpha_4 + \sum_{i=1}^{k-1} \beta_{41} \Delta GDP_{t-i} + \sum_{j=1}^{k-1} \beta_{42} \Delta REC_{t-j} + \sum_{l=1}^{k-1} \beta_{43} \Delta GCF_{t-l} + \sum_{i=m}^{k-1} \beta_{44} \Delta LNTLF_{t-m} + \sum_{i=n}^{k-1} \beta_{45} \Delta TO_{t-n} + \lambda ECT_{t-1} + \mu_{4t} \quad (7)$$

$$\Delta TO_t = \alpha_5 + \sum_{i=1}^{k-1} \beta_{51} \Delta GDP_{t-i} + \sum_{j=1}^{k-1} \beta_{52} \Delta REC_{t-j} + \sum_{l=1}^{k-1} \beta_{53} \Delta GCF_{t-l} + \sum_{i=m}^{k-1} \beta_{54} \Delta LNTLF_{t-m} + \sum_{i=n}^{k-1} \beta_{55} \Delta TO_{t-n} + \lambda ECT_{t-1} + \mu_{5t} \quad (8)$$

3.5 Determine the effect of renewable energy consumption on economic growth in Nigeria

In order to examine the effect of renewable energy consumption on economic growth in Nigeria. This study estimate In the above models, $\Delta LNGDP_t$, ΔREC_t, ΔGCF_t , $\Delta LNTLF_t$ and ΔTO_t are the first differences, representing short-term variation of the five constructs. ECT_{t-1} is the error correction term (the residual obtained from the cointegrating equation); p is the number of lag order; β is the estimation coefficient of the explanatory variables, representing short-term impacts on the dependent variable; and λ is the coefficient of correction, which represents the speed of adjustment from non-equilibrium to long-term equilibrium.

3.6 Investigate the direction of causality between renewable energy consumption and economic growth in Nigeria.

This study will also test for the causal relationship between renewable energy and economic growth using the granger causality approach. This study will therefore, make use of the two-step process of the Granger (1988) model to determine this. The granger causal relationship exists between variables if and only if the estimated probability value is less than 0.05.

4. Results and Discussion

4.1 Descriptive Statistics

Table 2: Descriptive Statistics Results of Real Gross Domestic Products, Renewable Energy Consumption, Capital Formation, Total Labor Force and Trade openness

	LNGDP	REC	GCF	LNTLF	TO
Mean	11.19787	85.05829	28.81542	17.67661	36.16016
Median	11.31106	84.96141	27.53981	17.69141	36.54016
Maximum	11.75905	88.68	53.18669	18.07282	53.27796
Minimum	10.4433	80.64	14.90391	17.27926	16.35219
Std. Dev.	0.438525	2.204404	11.06996	0.230512	9.393959
Skewness	-0.213969	-0.23862	0.385654	-0.04534	-0.15726

Kurtosis	1.410989	2.087046	2.096697	1.940346	2.465263
Jarque-Bera	3.610783	1.414998	1.881161	1.508117	0.513152
Probability	0.16441	0.492875	0.390401	0.470453	0.773696
Sum	358.332	2721.865	922.0935	565.6516	1157.125
Sum Sq. Dev.	5.961418	150.6413	3798.863	1.647204	2735.64
Observations	33	33	33	33	33

Source(s): Author's computations

The descriptive is measured, as shown in Table 2. For each variable, the total observation (count) is 33, reflecting the years (1990 to 2022) for this analysis. The result from the descriptive statistics shows that the mean of real gross domestic products, renewable energy consumption, capital formation, total labor force and trade are 11.19787, 85.05829, 28.81542, 17.67661, 36.16016 respectively. The mean measures the average value of the series, and this is obtained by summing up the value of the series in the current sample and dividing by the number of observations. The median of the variables are 11.31106, 84.96141, 27.53981, 17.69141 and 36.54016 respectively, this shows the variable in the middle, either in ascending or descending order. It was shown that all variable a median value that is very close to its mean values. The maximum and minimum values of the variables are the highest and lowest values of the series. Within the sampling range, the maximum value all the variables are 11.75905, 88.68, 53.18669, 18.07282, and 53.27796 respectively. The minimum values of the variables are respectively. The standard deviation for real gross domestic product, oil revenue, external debt, foreign direct investment, and inflation rate are 10.4433, 80.64, 14.90391, 17.27926 and 16.35219 respectively. Standard deviation measures the level of dispersion or spread of each series from its mean value.

The Jarque-Bera test for normality showed that the entire variable exhibited non-normality while all variables are not statistically significant, as the probability value is greater than 0.05. In addition, if the kurtosis of the variable is equal to 3 (excess ≈0) is called mesokurtic, while the kurtosis is less than 3 the variable distribution is called platykurtic. Further, if the kurtosis is greater than 3, the variable distribution is called leptokurtic. In line with this fact, all the variables reported kurtosis has less than 3. It implies that they are called Platykurtic, which means they have lighter tails than a normal distribution. In terms of skewness, all the variables were negatively skewed except for capital formation with value of 0.385654. This showed that the "tail" of all the variables except for capital formation have their distribution points tending toward the left. This occurred because the skewness values were less than zero (0) or positive.

4.2 Unit Root Tests

To ensure that the right methodology and estimate approach are applied, it is crucial to verify the stationarity properties of the data after the descriptive statistics. Given this, the results of two unit root tests—the Augmented Dickey-Fuller (ADF) test— is shown in Table 3. The result of the ADF test in **Table 3** shows that all the variables are stationary at the first difference at 5% level of significance.

Table 3: Stationary Test

ADF Units Root Test				
Variable	Intercept		Intercept with trend	
	I(0)	I(1)	I(0)	I(1)
LRGDP	0.8752	0.0021***	0.8543	-
REC	0.2033	0.0001***	0.3346	-
GCF	0.1307	0.0159**	0.9998	-
TLF	0.9968	0.0484**	0.7638	-
TOP	0.0686*	0.0001***	0.0781*	-

(*)Note: ***, ** & * denote significance level at 1%, 5% and 10% respectively. In ADF, the values are the probability value for testing the null hypothesis that the series has unit root and Lag Length based on SIC

Source: Author's computation (2024)

4.3 Determine the effect of renewable energy consumption on economic growth in Nigeria between 1990 and 2022

In order to achieve objective one (1) which seek to determine the effect of renewable energy consumption on economic growth, this session presents the appropriate lag length test, result of the co-integration test, the result of the VECM result, as well as the result of the diagnostic test of renewable energy consumption and economic growth.

4.3.1 Lag Length Criteria

To determine the optimal lag length of real gross domestic products (LNGDP), renewable energy consumption (REC), capital formation (GCF), total labor force (TLF) and trade openness (TOP) models of the study, standard VAR tool was employed. Table 4below shows the appropriate lag length of the VE model of objective two. It is evidence all of the lag selection criteria produced the same results.

Table 4: VAR Lag Length Selection

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-762.306	NA	1.13E+16	51.15371	51.38724	51.22842
1	-605.225	251.3289*	1.74e+12*	42.34834*	43.74953*	42.79659*
2	-581.077	30.58717	2.15E+12	42.40515	44.97401	43.22695

* indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information

Source: Author's computation (2024)

4.3.2 Co-Integration Test Result

In order to determine if there is a long-run relationship between the variables in the model for objective one, a cointegration test using the Johansen system of cointegration test. This was necessary because the variables in the model had the same orders of integration atI(1) and despite the fact that the series are drafting apart or trending either upward or downward the need cannot be underemphasize.The results of the co-integration in Table 5 confirmed that there is at most one co-integration relationship among the macro economic variables included in the model. Specifically, this test suggests that economic growth has equilibrium condition with renewable energy consumption, capital formation, total labour force and trade openness which keep them in proportion to each other in the long run. This evidence of co-integration among the variables rules out spurious correlations and applies that one direction of influence can be established among the variables.

Table 5: Result of Co-integration Test
Series: LNGDP REC GCFLNTLF TO
Lags interval 1 to 1

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
None *	0.650052	73.83746	69.81889	0.023
At most 1	0.555565	42.33833	47.85613	0.1495
At most 2	0.299477	18.00981	29.79707	0.5653
At most 3	0.155531	7.331985	15.49471	0.5393
At most 4	0.072583	2.260555	3.841466	0.1327

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
T.S. test indicates 1 cointegrating equation(s) at 5% significance level
Source: Author's computation (2024)

4.3.3 The Vector Error Correction Model Estimates

Table 6 Johansen Cointegration Test Result

Error Correction:	(1) D(LNGDP)	(2) D(REC)	(3) D(GCF)	(4) D(LNTLF)	(5) D(TO)
CointEq1	-0.592095***	7.920781**	1.576043	-510572.1	-5.972949
	(0.10739)	(2.88968)	(6.66077)	(1441161)	(16.6263)
D(LNGDP(-1))	0.116881	-1.267754	3.888329	-2068657	29.0206***
	(0.15217)	(4.09453)	(9.43798)	(2042053)	(23.5587)
D(REC(-1))	0.041475***	-0.362147	-1.15346	-14952.49	2.133588***
	(0.00879)	(0.23666)	(0.5455)	(118026)	(1.36164)

D(CF01(-1))	0.005851***	0.157748***	0.195937	60247.12***	-0.769059
	(0.00414)	(0.11139)	(0.25677)	(55555.6)	(0.64093)
D(TLF(-1))	-2.89E-08	8.26E-07***	4.14E-07	0.631379***	2.43E-06
	(1.60E-08)	(4.40E-07)	(1.00E-06)	(0.21783)	(2.50E-06)
D(TO(-1))	0.000393	-0.005022	-0.153916	-31553.66	-0.351053
	(0.0016)	(0.04296)	(0.09902)	(21425.3)	(0.24718)
C	0.144915**	-1.66955***	-4.113773*	1107978***	-3.534618
	(0.03361)	(0.90445)	(2.08477)	(451072)	(5.20391)
R-squared	0.742033	0.537734	0.375773	0.564456	0.585605
Adj. R-squared	0.575114	0.238621	-0.028139	0.282633	0.317467

*(**)*** denotes rejection of the hypothesis at 1%, 5% and 10% significance level

Source: Author's computation (2024)

Regression results are shown in Table 6. The degree of fit of the VECM is 0.7420, 0.5377, 0.3758, 0.5645, and 0.5856, respectively, which exceeds 0.50 except for model (3), and therefore indicates good fit. The positive value of 0.5921 is the error correction coefficient of model (1), which is significant at the 1% level, indicating that when economic growth increase rapidly, the system will adjust downward accordingly and eventually return to the long-term equilibrium state. The coefficient of model (2) and (3) are 7.9208 and 1.5760 respectively, although they violates the downward correction principle, the value are not significant. The coefficient of model 4 and 5 are −510572.1 and -5.9729 respectively, they exhibit positive values that reveals when economic growth increase rapidly, and the system will adjust downward accordingly and eventually return to the long-term equilibrium state.

For the other explanatory variables, in model (1) D(LNGDP(-1))ispositive but insignificant. The D(REC(-1))is positively correlated with the dependent at 1% significance level, and the absolute value of this coefficient is much larger than that of the other variables in model (1), reflecting that short-term sharp fluctuations in renewable energy consumption will lead to a significant increase in economic growth.Therefore, it is believed that the outcome overlapped the conclusion of Bužinskienė (2019); Salman and Hosny, (2017) and Shahbaz et al., (2020) that there exist a positive and significant relationship between renewable energy and economic growth.In addition, coefficients of D(GCF(-1)) is positively and significantly correlated with D(LNGDP) at 1% significance level. The coefficients of D(GCF(-1))is smaller than those of D(REC(-1))reflecting that the adjustment of short-term economic growth is primarily driven by renewable energies in model (1). In model (2) D(CF(-1)) and D(LNTLF(-1)) are positively correlated with the D(REC)at the significance level of 1% respectively. This relation indicates that when the capital formation and total labour forceper unit, renewable energy consumption increase by 0.16 and 0.0000008 units respectively and vice versa.

In model (3), variables such as D(LNGDP(-1)),D(GCF(-1)) and D(LNTLF(-1)) are positive correlated with D(GCF) but are insignificant. This shows that a percentage increase in economic growth causes capital formation to increase by 3.88 units while a unit increase in capital formation and total labour force would increase capital formation by 0.20 and 0.000000414 units respectively ceteris paribus. In model (4), D(GCF(-1)) and D(LNTLF(-1)) are positively and significant correlated at 1% significant level with D(TLF) . This revealed that a unit change in capital formation and previous total labour force would increase total labour force by 60247 and 0.63 units respectively and vice versa. In model (5), D(LNGDP(-1)) and D(REC(-1)) are positively and significant correlated at 1% significant level with D(TO). This revealed that a percentage increase in economic growth and a unit change in renewable energy consumption would increase trade openness by 29.02 and 2.13 units respectively and vice versa.

4.3.4 Diagnostics Test

In order to assess the robustness of the VECM model, several diagnostic tests were conducted and the results are presented in Table 7. The VEC Residual Serial Correlation LM test was used to check for serial correlation and it showed that there was no evidence of serial correlation in the model, as probability value was greater than the 5% level of significance. The presence of heteroskedasticity was tested using the VEC Residual Heteroskedasticitytest, which revealed that heteroskedasticity was not a problem in the model.

Table 7: Results of the Diagnostics Tests

Test	F-statistic	Prob. Value	Remarks
Serial correlation Test	0.519351	0.9518	No serial correlation
Heteroskedasticity Test	-	0.6598	No Heteroskedasticity

Source: Author's computation, 2024

4.4 Investigate the direction of causality between renewable energy consumption and economic growth in Nigeria

In table8, we fail to reject the null hypothesis which state that, "reject the null hypothesis when the probability value is less than 0.05". This implies that renewable energy consumption does not have a causal relationship with gross domestic product likewise; gross domestic product does not have a causal relationship with renewable energy consumption. From the result below, it was reported that there exist no causality at F-statistics (P- value) 2.13567 (0.1392) and 1.22532 (0.3107) running from renewable energy consumption to gross domestic product at 5% significant level and vice versa. This finding conforms to a-priori expectations and corroborates the view of Azeakpono and Lloyd (2020) that there is no causal link between the variables.Hence, the result indicates that there is no causality either unidirectional or bi-directional between renewable energy consumption and gross domestic product.

Table 8: Results of the Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
REC does not Granger Cause LNGDP	31	2.13567	0.1392
LNGDP does not Granger Cause REC	31	1.22532	0.3107

Source: Author's computation, 2023

5. CONCLUSION AND POLICY RECOMMENDATIONS

The research revisits the effect of renewable energy consumption on economic growth in Nigeria from 1990 to 2022. This study is important because it shows the relationship between renewable energy and economic growth and other explanatory variables such as capital formation, total labor force and trade openness using dynamic modelfor Nigeria. Ithas been shown that short-term fluctuations in renewable energy consumption significantly influence economic growth, even more than capital formation. This shows investing in renewable energy can be an important economic strategy. The result also shows the two major variables have a long run relationship between them. These highlight the importance of sustainable energy policies through the creating jobs, reducing energy costs, and increasing energy security. Based on the findings of this study, the following measures are recommended for mobilizing and harnessing renewable energy consumption to increase economic growth and development in Nigeria.

I. The relationship that exist between renewable energy use, economic growth and other variables used in the study shows that Nigerian government can support and promote the use of renewable energy by enacting policies and providing incentives for households, businesses, and industries to switch to renewable energy sources. This can include tax credits, subsidies, and low-interest loans for renewable energy projects.

II. Capital formation and total labor force playing a significant impact on renewable energy use indicating the need for investment in renewable energy technologies and infrastructure, which can help to increase the availability and affordability of renewable energy, improve workforce development in Nigeria renewable energy sector. This can include investment in solar panels, wind turbines, and other renewable energy technologies, as well as the construction of new renewable energy plants and the expansion of existing ones.

III. Research and development of new renewable energy technologies can help to improve the efficiency and affordability of renewable energy in Nigeria. This can include the development of new energy storage technologies, the improvement of existing technologies, and the exploration of new renewable energy sources.

IV. The positive inter-link between economic growths, renewable energy use and trade opennessindicates the need to collaboration with international organizations and countries can help to increase the availability and affordability of renewable energy in Nigeria. This can include partnerships for technology transfer, capacity building, and knowledge sharing, as well as joint investment in renewable energy projects.

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