Energy Economics Letters
ISSN(e): 2308-2925
DOI: 10.55493/5049.v10i2.4900
Vol. 10, No. 2, 90-105.

URL: www.aessweb.com

The impact of educational attainment on the transition from nonrenewable to renewable energy use in Nigeria

Olufemi Muibi Saibu[1+]
Opeyemi Balikis Olagunju[2]

[1,2]*Institute of Nigeria China Development Studies, University of Lagos, Nigeria.*
[1]*Email: osaibu@unilag.edu.ng*
[2]*Email: balikisopeyemi69@yahoo.com*

(+ Corresponding author)

Article History
Received: 16 August 2023
Revised: 12 October 2023
Accepted: 23 October 2023
Published: 2 November 2023

Keywords
Climate change
Economic growth
Education attainment
Nigeria
Renewable energy.

JEL Classification:
I25; Q42; Q57; O13; N17.

ABSTRACT

This paper examines the role of education in promoting renewable energy in Nigeria based on data from 1990 to 2021 using FMOLS second-generation cointegration to estimate two proxies of renewable energy. It also examines how economic growth spurs education as a driver of energy transition and tests the energy mix hypothesis in Nigeria by employing real economic growth and the import of fossil fuels as controllable variables in a model with four education indicators. The results showed that education is vital to Nigeria's renewable energy goals. In contrast to existing studies, the study established that all types of education encourage the move from nonrenewable to renewable energy consumption in Nigeria. However, technical and university education are the most crucial in Nigeria's drive toward the adoption of renewable energy, which implies that Nigeria's energy transformation may require more than general knowledge. The paper also established that to mitigate the influence of Nigeria's low economic growth on its energy transition, a minimum critical level of at least 7% of the per capita income and 7%–9% of higher technical education must be attained consistently. The paper concludes that purchasing power measured by economic growth is more important than education for Nigeria's energy shift. However, education can mitigate the detrimental effects of economic growth on energy transition potential. Therefore, policy to promote energy transition with technical educational development and economic empowerment is needed to achieve Nigeria's energy transformation goal.

Contribution/ Originality: This paper contributes to existing literature by accounting for all forms of education and estimating the relative contribution of each form of energy to the transition to renewable energy. In addition, it establishes not only the required per capita income but also the minimum level and type of education needed for a seamless transition to renewable energy in Nigeria.

1. INTRODUCTION

Promoting improved environmental quality and the transition to green energy sources is becoming a top priority in developing countries such as Nigeria. In today's world, energy is crucial to economic advancement and is a primary predictor of economic development in developed and developing countries. In recent decades, nonrenewable energy sources are being phased out (Moustapha, Yu, & Danqauh, 2021). Concerns regarding fossil fuels, the primary source of global emissions and climate change, are forcing countries to look into sustainable energy alternatives (Kazar & Kazar, 2014). Since the 1992 United Nations Framework Convention on Climate Change (Nations, 1992) CO_2 emissions from energy and industry have increased by 60%. Furthermore, Sustainable Development Goal 7 of the United Nations General Assembly on affordable and clean energy proposes increasing the share of renewable energy used in energy consumption. Renewable energy is also a critical component of the circular economy because it generates no waste while increasing the availability of finite energy sources (Sart, Bayar, Sezgin, & Danilina, 2022).

Renewable energy and energy efficiency have emerged as critical variables for decarbonization, sustainable economic growth, and a circular economy in this context. Energy demand is expected to rise by 40% by 2040, requiring the proportion of renewable energy in the overall energy consumption to rise by 66% and energy intensity to rise by 3.2% each year (IRENA, 2019). Rising energy costs as a result of increased demand and insufficient supply, dwindling nonrenewable energy reserves, and environmental concerns over the usage of fossil fuels triggered the energy transition debate. Researchers and policymakers have concentrated on institutions, economic freedom and its components, economic growth, real GDP per capita, human capital, human development, energy investments, energy dependence, intellectual property rights, urbanization, research and development (R&D) spending, technological development, population growth, and trade openness (Marques, Fuinhas, & Manso, 2010), neglecting the critical consequential losses and attendance costs of only focusing on "*greenless growth*". Access to renewable energy is vital for environmental health, economic growth and development, and human development by encouraging a better lifestyle (Saibu & Omoju, 2016). Education is critical to increasing access to clean energy, as a lower degree of education is frequently related to poorer income, a lack of environmental awareness, and a lower tendency to accept new renewable energy technologies. Equally, renewable energy production necessitates higher educational attainment and human development. Therefore, theoretically, there should be a symbiotic relationship between educational attainment and renewable development (Sasmaz, Sakar, Yayla, & Akkucuk, 2020).

This paper contributes to current literature in two ways. Unlike in other emerging markets, few studies in Africa have looked at the causal relationship between secondary or tertiary school enrollment as proxies for educational attainment and renewable energy and these studies frequently fail to account for country-specific features (Aguirre & Ibikunle, 2014; Omri, Nguyen, & Rault, 2014; Pfeiffer & Mulder, 2013; Sart et al., 2022). This article explores the interaction between educational attainment and renewable energy at the country level, taking country-specific features into account. The main aim of this study is to estimate the impact of education on the switch from nonrenewable to renewable energy consumption using data from 1990 to 2021 in Nigeria. The paper is organized as follows: Section 2 covers the theoretical foundation and empirical literature on the relationship between educational attainment and renewable energy; the dataset and analytic approach are described in Section 3; the empirical analysis is presented in Section 4; and Section 5 concludes and provides policy implications.

2. LITERATURE REVIEW

Education has been cited as a key driver of economic growth and innovation, as well as a means for governments to promote education on energy, renewable energy adoption, and reduced energy consumption. In this regard, Inglesi-Lotz and Morales (2022) investigated the causal and empirical relationship between primary energy consumption and education from 1980 to 2013 for developed and developing countries. The findings indicate that there is a one-way relationship between energy consumption and education, with education leading to increased energy consumption. Another intriguing discovery is the confirmation of a nonlinear relationship between energy consumption and education; higher levels of education in developing nations increase energy consumption, whereas higher levels of education in developed nations decrease energy consumption. This article argues that developed nations should promote pro-education policies to reduce energy consumption, whereas developing nations should combine education with environmental awareness initiatives to mitigate the impact of increased education on energy consumption.

Similarly, renewable energy has piqued the interest of academics in recent years, and the number of scholarly articles on the topic has increased. Sasmaz et al. (2020) examined the relationship between renewable energy and human development in 28 OECD (Organization for Economic Cooperation and Development) countries between 1990 and 2017. According to their findings, renewable energy has a positive effect on human development, and they discovered a bidirectional causal relationship between renewable energy and human development. Sahoo and Sethi

(2020) examined whether remittance inflows stimulated electricity use in India in conjunction with other macroeconomic variables, such as FDI, trade openness, and urbanization, in the energy demand function. The paper utilized structural break and cointegration analyses to determine stationarity and the long-run relationship between the variables, and it used Toda–Yamamoto causality to examine the causal relationship between the variables. Using an innovative accounting approach, the robustness of the causality links was also assessed. According to the study, remittance inflows increased India's electricity consumption. Industrial expansion is positively correlated with electricity demand, and urbanization increases electricity consumption, while trade liberalization decreases it. As a result of the positive effects of remittance inflows, trade openness, and urbanization, the paper concluded that policymakers in the Indian economy must design sustainable environmental policies carefully. Therefore, any long-term environmental policy aimed at preserving the natural environment will impede the growth of remittances, urbanization, and investment. Without a long-term environmental policy, it could be argued that India's long-term development is impossible. Menyah and Wolde-Rufael (2010) examined the relationships between renewable energy consumption, nuclear energy consumption, and CO_2 emissions in the United States from 1960 to 2007. Their study demonstrated that CO_2 Granger-causes renewable energy use and that there is a negative unidirectional causal relationship between nuclear energy use and CO_2. Mallick (2009) utilized the Granger causality test and a vector autoregression variance decomposition analysis in his study. According to the findings, there is a unidirectional relationship between economic development and petroleum demand. In the case of coal consumption, causality is reversed. It also demonstrates a bidirectional causal relationship between economic development and energy consumption. Farhani (2013) examined the relationship between renewable energy consumption, economic growth, and CO_2 emissions for 12 MENA countries between 1975 and 2008. It was discovered that MENA countries have not identified the best policy to regulate renewable energy prices, which would bring stability to the economic growth structure and reduce pollution emissions. Li, Dong, Xue, Liang, and Yang (2011) analyzed 28 Chinese provinces and established a two-way causal relationship between energy consumption and economic growth. Long-term CO_2 emissions are controlled by economic development and energy consumption.

Using a neoclassical growth function, Dees and Auktor (2017) discovered that an increase in the generation of renewable energy has a positive impact on economic development in the MENA region. They concluded that investing in renewable energy benefits numerous MENA countries and panels, which could serve as an incentive to strengthen the region's existing renewable energy strategy. In an analysis of the causal relationship between energy consumption, CO2 emissions, and income in India, Alam and Butt (2002) found that energy use and long-term CO_2 emissions are causal in both directions. The research found no correlation between other characteristics and income. According to the authors, energy conservation programs can be implemented without affecting economic development, but the lack of causality in any direction will make CO_2 reduction in India more difficult.

Aïssa, Jebli, and Youssef (2014) analyzed the consumption, trade, and output of renewable energy in 11 African nations from 1980 to 2008. In the short term, there was no evidence of a causal relationship between output and renewable energy consumption, or between commerce (exports or imports) and renewable energy use. However, the estimates indicate that renewable energy use and trade have a statistically significant and positive impact on output over the long term. Sadorsky (2009) used a panel VECM and a panel cointegration technique to conduct a study of G7 countries from 1980 to 2005. He found that the long-term movement in renewable energy per capita consumption is primarily explained by CO_2 emissions and GDP per capita. The results indicate that when the short-term consumption of renewable energy deviates from its equilibrium trajectory, it returns to equilibrium via long-term equilibrium movements. Aïssa et al. (2014) used the ARDL bounds testing approach and vector error correction model (VECM) to examine the causal relationship between economic growth and renewable energy consumption in BRICS countries from 1971 to 2010. The empirical evidence indicates that the variables have long-term equilibrium correlations and two-way Granger causality, implying the feedback hypothesis, which can explain the role of renewable energy in promoting economic growth in BRICS nations. Using cointegration and causality analyses, Satrovic (2018) examined the relationship between renewable energy and human development in Turkey between 1992 and 2015 and discovered significant one-way causality from renewable energy to human development. The relationship between renewable energy, economic indicators, and pollution emissions in 28 OECD member countries between 2004 and 2015 using a simultaneous equation system revealed that human capital had a positive effect on the use of renewable energy. Lekana and Ikiemi (2021) utilized cointegration analysis to examine the impact of energy consumption on human development in the economies of the Economic and Monetary Community of Central African States. They discovered that the use of renewable energy had no effect on the development of the sample population.

Farabi and Abdullah (2020) analyzed the effect of energy consumption, economic growth, population, and foreign direct investment (FDI) on CO_2 emissions in Indonesia and Malaysia from 1960 to 2018 using disaggregated CO_2 emissions and energy consumption statistics, specifically for oil, coal, and natural gas. The article applied the ordinary least squares method, followed by the unit root and classical assumption tests. The results indicate that economic growth has the greatest impact on CO_2 emissions from oil and natural gas, while population has the greatest impact on CO_2 emissions from coal. The paper concluded that the economic development of both nations is substantially dependent on fossil fuels. Population has the greatest impact on CO_2 emissions from coal due to the high demand for electricity from residences, which is met by power generation that uses coal as a fuel. The report also supported the environmental Kuznets curve hypothesis, which states that natural gas is the most appropriate source of energy to use at a specific level, and that the use of natural gas effectively reduces CO_2 emissions while simultaneously increasing economic growth. Natural gas is also regarded as the most eco-friendly fossil fuel because it emits less carbon dioxide than oil and coal. The findings have significant implications for policymakers as they make policy and business decisions, particularly with regard to promoting environmentally favorable energy use for economic benefit.

Saibu and Omoju (2016) argued that the adoption of renewable electricity technology is crucial for mitigating climate change and promoting sustainable development. They investigated the main drivers and barriers to renewable electricity technology adoption in Nigeria using data from 1981 to 2011 and the Johansen cointegration technique and the vector error correction method. The results indicate that trade openness promotes the consumption of renewable electricity in Nigeria, whereas a preoccupation with economic growth and lobbying for conventional energy sources hinder it. It is suggested that the Nigerian government implement measures that increase not only the quantity of renewable electricity, but also the proportion of total electricity consumption derived from renewable sources. According to Lasantha and Nawarathna (2022), the use of fossil fuels is a significant contributor to global warming due to the greenhouse effect; therefore, renewable energy is the most eco-friendly alternative energy source. Earlier studies that demonstrated the significant influence of financial development and education on renewable energy were criticized for failing to examine the concomitant effects of these two factors on renewable energy, especially in emerging economies. Using dynamic, and seemingly unrelated, cointegrating regression and the Dumitrescu–Hurlin causality test, the study investigated the impact of education and financial development on the use of renewable energy in eleven countries from 1990 to 2016. The empirical findings revealed that financial development significantly increased the consumption of renewable energy, while education had no effect.

According to Inglesi-Lotz and Morales (2022), the importance of education in the development process has prompted governments to promote energy education as a means of increasing the deployment of renewable energy and reducing energy consumption. The article examined the causal and empirical relationship between primary energy consumption and education for a group of developed and developing countries and an aggregate cohort of developed and developing country groups for the period from 1980 to 2013. The findings support a unidirectional relationship between energy consumption and education, in which energy consumption causes education. The results also revealed a nonlinear relationship between energy consumption and education, implying that higher levels of education in impoverished nations increase energy consumption, whereas higher levels of education in wealthy nations decrease energy consumption. The report recommends that wealthy nations implement pro-education policies to reduce energy consumption, whereas developing nations should combine education with environmental awareness programs to mitigate the effect of increased education on energy consumption.

Given the finite reserves of nonrenewable energy and the worldwide environmental degradation caused primarily by nonrenewable energy consumption, Sart et al. (2022) asserted that renewable energy is a crucial component of circular economies, sustainable development, and the environment. Using causality and cointegration analyses, this study examines the impact of educational attainment and economic growth on renewable energy use in selected emerging markets from 2000 to 2018. According to the causality analysis, there is a substantial unidirectional correlation between indicators of educational attainment and economic growth and the consumption of renewable energy. In other words, indicators of educational attainment and economic growth are significant short-term determinants of renewable energy. In addition, the cointegration analysis demonstrated that measures of educational attainment and economic growth have a positive influence on the adoption of renewable energy over the long term. Both studies found that educational attainment and economic growth have substantial immediate and long-term effects on the consumption of renewable energy. Thus, educational attainment policies can be used to increase the proportion of renewable energy consumption relative to total energy consumption.

3. EMPIRICAL METHOD

3.1. Model Specification and Data

The dynamic relationship between educational outcomes and renewable energy consumption was modelled utilizing two renewable energy proxies—total renewable energy and renewable energy electricity components—as a percentage of total energy consumption. The following is an overview of the model:

$$RNE^i = \alpha_0 + \beta_1 EDUC^i + \beta_2 GDPC + \varepsilon_t \qquad (1)$$

Where RNE^i is renewable electricity (RNEC) and total renewable energy consumption (RNENC) as ratio of total energy consumption; $EDUC_t$ is educational outcome proxied by its components—primary school education (PSE), secondary school education (SSE), technical school education (TSE) and university education enrollment (EEU); $GDPC_t$ is economic growth captured by gross domestic product per capita (GDPC); and εt is the error term. In addition to the target variables, two others are included as explanatory variables, fossil fuel energy consumption (FFE) and energy import (ENIM), thus Equation 1 becomes:

$$RNE^i = \alpha_0 + \beta_1 EDUC^i{}_t + \beta_2 GDPC_t + \beta_3 FFE_t + \beta_4 ENIM_t + \varepsilon_t \qquad (2)$$

These variables are included to account for the complementary and substitutability roles that fossil fuels and imports can play in aiding and hindering the transition. For example, the adoption of renewable energy is dependent on how much of these energy technologies can be imported, as most renewable energy technologies are not manufactured in Nigeria. We employ the energy component rather than total commerce or import to capture energy import. The use of fossil fuels will undoubtedly have an impact on the uptake and utilization of renewable energy.

Equation 2 was estimated for RNEC and RNENC with total educational enrollment and the disaggregated components (SEP, SES, SET, TEU), respectively. This means that Equation 2 will estimate four models for each of the two renewable energy components being considered, so a total of eight models will be estimated. We introduce an interaction term between economic growth and educational attainment into the equation to determine whether economic growth and per capita income have any significant influence on the role of educational attainment in the adoption and transition from nonrenewable to renewable energy.

$$RNE^i = \alpha_0 + \beta_1 EDUC^i{}_t + \beta_2 EG_t + \beta_3 FFE_t + \beta_4 ENIM_t + \beta_5 EDUC^i * GDPC_t + \varepsilon_t \qquad (3)$$

Therefore, with the interaction term, the effect of educational enrollment is dependent on the level of per capita income in that particular year. The per capita income required to enhance the impact of educational attainment and outcome on energy transition to renewable energy is calculated as follows:

$$\frac{\delta RNE^i}{\delta EDUC^i{}_t} = \beta_1 + \beta_5 GDPC_t \quad (4)$$

Solving Equation 4 in terms of GDPC implies that:

$$\overline{GDPC} = \frac{-\beta_1}{\beta_5} \quad (5)$$

Equation 5 shows that the minimum amount of economic growth required to stimulate renewable energy consumption is equal to the negative ratio of the coefficient of individual education and the coefficient of the interaction between education and economic growth in Equation 4.

3.2. Data Description and Sources

The transition from nonrenewable to renewable energy was assessed by examining changes in the proportion of renewable energy consumption relative to total energy consumption. As the ratio increases, there is a corresponding increase in the transition from nonrenewable to renewable energy sources. This ratio can serve as a means of tracking and analyzing patterns and fluctuations in the utilization of renewable energy as opposed to nonrenewable energy within the context of Nigeria. Renewable electricity energy consumption is primarily driven by electricity, which serves as the principal component in Nigeria. The model employed in this study focuses on isolating the variations in renewable electricity energy consumption. The model's dependent variables are total renewable energy consumption (RNENC) and renewable electricity consumption (RNEC), expressed as a proportion of the overall final energy consumption. The primary focal point of the approach pertains to educational achievement.

Table 1. Variables and their symbols.

Variable	Symbol	Definition
Dependent	LRNENC	Total renewable energy consumption
	LRNEC	Renewable electricity energy consumption
Independent	LSSE	Secondary school enrollment
	LPSE	Primary school enrollment
	LTSE	Technical school enrollment
	LUEE	University education enrollment
Control	LGDPC	Economic growth
	LFFE	Fossil fuel energy
	LENIM	Energy import

Note: The data for all variables were sourced from the World Bank's World Development Indicators and complemented with CBN's 2021 annual statistics.

The four educational outcomes comprise primary, secondary, technical and university education outcomes. More specifically, the focus of this study is on the rates of primary school enrollment (PSE), secondary school enrollment (SES), technical school enrollment (TSE), and university education enrollment (UEE). The various categories of school enrollment rates are determined by the ratio of total enrollment to the population within the age group that corresponds to a specific level of education, as stated in the World Bank's Development Indicators. All the series listed in Table 1 are annual and encompass the period from 1990 to 2021. The econometric research utilized the logarithmic transformations of the series (denoted as L).

3.3. Method of Analysis

The fully modified ordinary least squares (FMOLS) method was used to calculate Equation 2. The unit roots and cointegration properties of the variables were confirmed and integrated before the estimation. The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) techniques were used to determine the variables' stationary characteristics. Following the establishment of the series' properties, Model 3 was estimated using the FMOLS model developed by Phillips and Hansen (1990) and Phillips and Moon (1999). The FMOLS model provides a mechanism to address the deficiency in the OLS technique when the variables are non-stationary but cointegrated. To attain asymptotic efficiency and establish the existence of cointegrating relationships among the variables, it accounts for serial correlations and endogeneity in the regressors.

4. EMPIRICAL RESULTS

4.1. Descriptive Analysis

The trends in renewable and nonrenewable energy consumption, educational attainment, and economic growth in Nigeria from 1990 to 2021 are depicted in Table 2 and Figure 1. Figure 1 illustrates the growth rate of the educational attainment variables and energy consumption. It shows that the total renewable energy consumption (LRNENC) remained constant as the average growth rate was zero. Renewable electricity consumption (RNEC) increased but fluctuated substantially, as indicated by the positive maximum and negative minimum as well as the magnitude of the standard deviation. Fossil fuel energy consumption (FFEC) also significantly fluctuated, yet, on average, had no growth rate over the period. Energy import (ENIM) was on the increase, and there was also evidence of fluctuation in the growth rate. Apart from university education, which had an average growth rate of zero, all other educational attainment outcomes experienced growth. Primary school education had the highest growth rate of 39%, followed by secondary school education with 14%. Technical school education experienced the highest rate of drop-outs with a negative growth rate of 23%, while secondary school education experienced no drop out as its minimum growth rate was positive (4%), unlike other educational attainment outcomes, which had negative growth rates at some point during the period. There are no apparent systematic relationships between the variables depicted in the graph. While there were some similarities in the various types of educational attainment, the components of energy consumption differed significantly from educational attainment, and no evident causal relationship was observed between these educational attainments and renewable energy consumption. Therefore, empirical research is required to determine the nature of the relationship between renewable and nonrenewable energy consumption, educational attainment, and economic growth in Nigeria.

Table 2. Descriptive statistics of renewable energy and educational attainment.

Variable	D(LRNEC)	D(LRNENC)	D(LPSE)	D(LSSE)	D(LTSE)	D(LUEE)	D(LFFEC)	D(LENIM)	D(LGDPC)
Mean	-0.04	0.00	0.02	0.06	0.03	0.00	0.00	-0.02	0.19
Median	-0.04	0.00	0.02	0.05	0.05	0.00	0.00	-0.03	0.14
Maximum	0.25	0.03	0.39	0.14	0.09	0.05	0.13	0.11	0.56
Minimum	-0.20	-0.03	-0.11	0.04	-0.23	-0.05	-0.21	-0.20	0.05
Std. dev.	0.09	0.02	0.09	0.02	0.06	0.02	0.07	0.06	0.12
Skewness	1.01	0.27	2.29	1.74	-3.20	-0.33	-1.06	-0.34	1.29
Kurtosis	5.40	1.97	11.40	5.90	13.72	3.31	4.46	4.25	4.40
Jarque–Bera	12.75	1.73	118.37	26.43	201.30	0.69	8.57	2.60	11.16
Probability	0.00	0.42	0.00	0.00	0.00	0.71	0.01	0.27	0.00
Sum	-1.27	-0.07	0.74	1.81	1.00	0.02	-0.07	-0.47	5.87
Sum sq. dev.	0.23	0.01	0.22	0.02	0.10	0.01	0.15	0.12	0.42

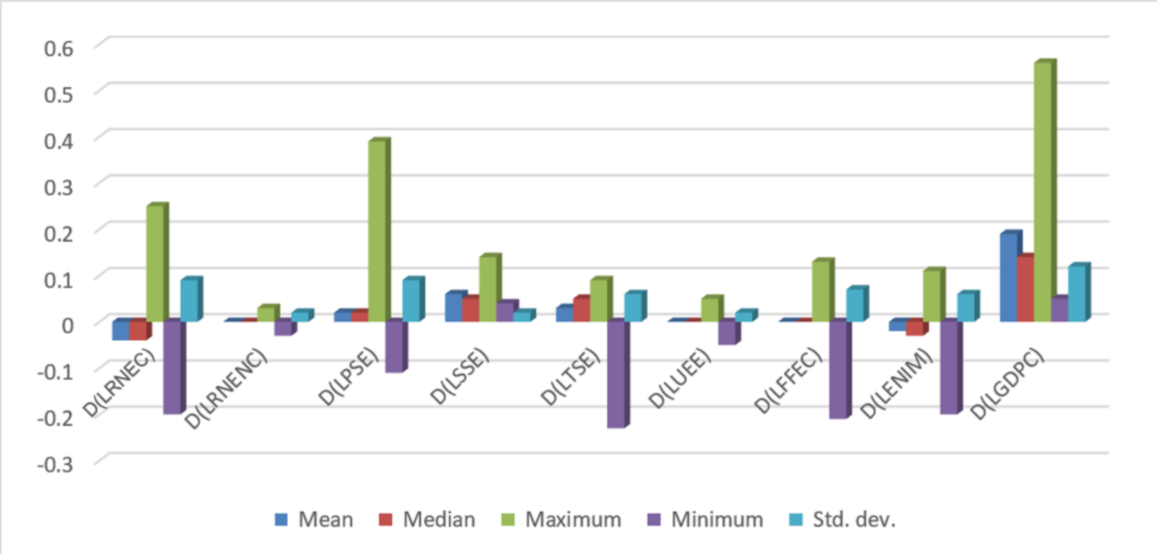

Figure 1. The average growth rates of renewable energy and educational attainment in Nigeria.

Total renewable energy consumption (LRNEC) declined, on average, from 1990 to 2021, with the highest growth rate of 25% in 1991 and the biggest drop of 20% in 2006. Renewable electricity energy consumption (LRNENC) has the least variability, with a maximum growth rate of 3% and a minimum of -3%. With the start of democratic administration in Nigeria, primary school education (PSE) outcomes experienced an average growth rate of 40% in 2000, while it suffered the slowest growth rate of 11% in 1997. Secondary school education (SSE) fluctuated less and grew more steadily during that time than primary school education. Over the period, it maintained a healthy growth rate which varied between 4% and 14%. Technical school outcomes had a peak growth rate of 9% in 1992 but experienced a 23% drop in 2010, whereas university education outcomes experienced a moderate fluctuation, with a peak growth rate of 5% and a minimum negative growth rate of 5%. It also has one of the lowest standard deviations, along with secondary outcomes and electricity renewable energy consumption. Patterns of fossil fuel consumption and energy import are comparable, with maximum growth rates of 11% and 13%, respectively, as well as dramatic negative growth rates of more than 20%.

Table 3. Unit root test results.

Series	ADF		PP	
	Level	1st difference	Level	1st difference
LGDPC	--1.657	-3.580	-1.323	-4.670
LRNEC	-0.191	-7.661	--1.749	-7.744
LRNENC	-2.536	-5392	-2.536	-5.394
LSSE	-1.651	-3.575	-3.568	-5.283
LTSE	-2.261	-5.705	-2.428	-6.349
LUEE	-1.509	-4.946	-1.629	-4.985
LPSE	-2.740	-3.721	-2.516	-6.664
LEDU	-2.136	-5.100	-2.081	-6.133
LENIM	-2.276	-7.076	1.971	16.971
LFFEC	-2.729	-5.706	-2.670	6.131
Critical values				
1% level	-4.285	-4.297	-4.285	-4.297
5% level	-3.563	-3.568	-3.563	-3.568
10% level	-3.215	-3.218	-3.215	-3.218

The variables' stationarity was tested using the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests. The results are shown in Table 3 and demonstrate that all the variables were non-stationary at the 5% level of significance, prompting a test at first difference, which showed that all of the variables are stationary at the first difference, that is, integrated of order I(1). After the stationarity is determined, the cointegration relationship between the variables is investigated.

Table 4. Summary of the cointegration estimates.

Model I: (LRNEC) (LPSE) D(LSSE) (LTSE) D(LUEE) (LFFEC) (LENIM) (LGDPC)				
Hypothesized no. of CEs	**Trace statistic**	**0.05 critical value**	**Max eigen statistic**	**0.05 critical value**
None *	275.989	159.530	91.085	52.363
At most 1 *	184.904	125.615	55.666	46.231
At most 2 *	129.238	95.754	42.345	40.078
At most 3 *	86.893	69.819	34.450	33.877
At most 4 *	52.443	47.856	28.527	27.584
At most 5	23.915	29.797	13.683	21.132
At most 6	10.232	15.495	8.788	14.265
At most 7	1.444	3.841	1.444	3.841

Note: The trace test and max-eigen statistics indicate five cointegrating eqn(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.

The null hypothesis of no cointegration for r = 0 to r = 4 was rejected by both the trace statistics and the maximum eigenvalue statistics for the total renewable energy (RNEC) and renewable electricity energy consumption models, respectively, as shown in Table 4. These statistical values exceeded their respective critical values. Nevertheless, the null hypothesis of no cointegration (r = 5) could not be rejected by the trace statistics because its value was below the crucial value. The cointegration test using the maximum eigenvalue and the trace statistics revealed five cointegrating equations with a significance level of 5%. There is a long-term association between renewable energy usage, educational attainment, and other energy consumption and Nigeria's economic growth.

Having confirmed multiple long-run relationships among different combination of the variables, the long-run estimate of the cointegration was analyzed. For the first model involving LRNEC, LPSE, LSSE, LTSE, LUEE, LFFEC, LENIM and LGDPC, first long-run relationship is expressed as follows:

Model I: Long-run cointegration for total renewable energy consumption (Equation 6):

$$LRNEC_t = 0.50 + 0.16LPSE_{t-1} + 1.67LSSE_{t-1} + 0.68LTSE_{t-1} + 4.41LUEE_{t-1} - 0.02LFFEC_{t-1} - 0.44LENIM_{t-1} - 0.27LGDPC_{t-1} + \varepsilon_t \quad (6)$$

t: [2.82] ** [3.21] ** [8.90] *** [8.54]*** [15.26]*** [-2.15]** [-6.239]** [-7.105]***

Model II: Long-run cointegration for renewable electricity energy consumption (Equation 7):

$$LRNENC_t = 0.758 - 0.01LPSE_{t-1} - 0.557LSSE_{t-1} + 0.15LTSE_{t-1} - 0.23LUEE_{t-1} - 0.10LFFEC_{t-1} - 0.02LENIM_{t-1}\ 0.04LGDPC_{t-1} + \varepsilon_t \quad (7)$$

t: [5.091] ** [-0.04] ** [-9.60] *** [5.78]*** [2.39]*** [-3.59]** [-0.85]** [0.0112]***

The cointegrating long-run results revealed that all four variables of educational outcomes were positive and statistically significant. This indicates that the lowest level of education is as significant as the highest level of education in supporting the shift away from the utilization of nonrenewable energy sources in Nigeria. Since renewable energy, unlike traditional energy sources, requires some knowledge and technicalities, many renewable energy appliances and technologies may not be adopted without proper education and the ability to read. However, with improved general and technical education and skills, there is potential for people to shift to a cleaner, higher level of hierarchy on the energy ladder. As expected, the usage of fossil fuels has a detrimental impact on the transition to renewable energy when compared to other variables that serve as controls. It suggests that fossil fuels are more of a substitute for renewable energy than a complement. There are instances where they may be complementary, such as when individuals embrace an energy mix where fossil fuels and renewable energy are used in variable proportions. However, findings show that this is not always the case. The evidence suggests that renewable energy adoption in Nigeria will be less likely as long as fossil fuels remain relatively inexpensive and renewable energy remains expensive. Importing energy also has a detrimental effect on renewable energy adoption in Nigeria. The greater the government's importation of fossil fuels to supplement domestic output, the less probable it is that individuals will switch to greener energy sources. The level of income is an additional crucial issue that has impeded the transition to renewable energy in Nigeria. The low per capita income and purchasing power of the masses hinder their ability to acquire and utilize renewable energy. Renewable energy technology is relatively costly, requiring a sizeable portion of the population's income to acquire and maintain. Hence, the level of income may diminish the potential benefits of greater education on renewable energy consumption in Nigeria. Analyzing the transition to renewable energy from the perspective of electricity revealed a considerable difference from when total energy was utilized. Only technical and university education became beneficial and relevant in this instance. Primary and secondary schooling appear insufficient to encourage Nigerians to adapt and switch to greater renewable energy usage. In light of this, general education may not be sufficient to facilitate energy transformation in Nigeria. Domestic fossil fuel energy consumption and imports continue to be a major barrier to Nigeria's renewable energy transformation. Per capita income had a favorable but insignificant impact on renewable energy usage, consistent with past findings based on total energy consumption. The sensitivity of the model was tested by employing the fully modified ordinary least squares (FMOLS) technique to separately estimate the two models with the individual education results. The findings of the two models for total renewable energy and electrical energy are reported in Tables 5a and 5b, respectively. According to Table 5a, economic growth, defined by per capita income, had a negative effect on total renewable energy use regardless of how educational attainment was measured or proxied. Fossil fuels were also crucial in increasing the usage of renewable energy in models that employed technical and secondary education as proxies for educational achievement. As an example of nonrenewable energy, fossil fuels seem to have a complementary effect on renewable energy. This indicates that Nigerians use both nonrenewable and renewable energy sources concurrently to complement each other. However, with a greater share of nonrenewable energy being used, renewable energy is only used as a stopgap remedy in Nigeria when there is a fossil fuel supply constraint. The combined influence of fossil fuels and economic growth demonstrates that purchasing power is a crucial factor in Nigeria's use of renewable energy. Regarding the variables of interest, education attainment and outcomes, only technical school education is significant in supporting the shift from nonrenewable to renewable energy consumption in Nigeria. Primary, secondary, and even university education are not as crucial as technical school education. Model II, with renewable electricity usage, yields comparable results to the model with total renewable energy. In most cases, economic growth and fossil fuels play a significant and complementary role. In Nigeria, technical school education is the most influential educational achievement in the transition to renewable energy.

Table 5a. Estimate of the effects of education on total renewable energy consumption.

Variable	Model II (TSE)	Model III (SSE)	Model IV (PSE)	Model V (UEE)
C	-2.669 (-1.08)	-3.892	-13.139 (-3.297)	-15.705 (-3.165)
LGDPC	-0.172 (-2.827**)	0.058 (0.422)	-0.097 (-2.402**)	-0.078 (-2.490**)
LFFEC	1.865 (8.057**)	2.123 (8.535**)	0.096 (0.284)	0.043 (0.120)
LENIM	0.323 (1.074)	0.411 (1.293)	2.339 (10.497**)	2.033 (9.495**)
LTSE	0.668 (2.047**)			
LSSE	-	-0.363 (-0.728)		
LPSE			0.483 (1.775)	
LUEE				1.775 (1.88)
Adjusted R-squared	0.93	0.91	0.91	0.92
S.E. of regression	0.119	0.136	0.135	0.013

Note: ** represents significance at the 5% critical level.

Given the complementary roles and potential effects of economic growth on the role of education, the education and economic growth variables interacted to determine the moderating effect of economic growth on education and renewable energy. The outcomes are presented in Tables 6a and 6b. The most critical aspect for interpretation is the relationship between economic growth and educational achievement. Individually, technical education and economic growth have a negative effect on renewable energy; although the influence of economic growth was large, the effect of technical education was negligible. However, when technical education interacts with economic growth, it becomes significant but remains negative, indicating that the amount of income, measured by economic growth, has an overwhelming impact and negative consequences for the interactive term.

Table 5b. Estimate of the effects of education on renewable electricity energy consumption.

Variable	Model I (EDU)	Model II (TSE)	Model III (SSE)	Model IV (PSE)	Model V (UEE)
C	4.901	4.834 (20.125)	6.118 (12.309)	4.419 (7.446)	4.669 (7.013)
LGDPC	-0.008 (-2.21**)	-0.002 (-0.443)	0.021 (1.507)	-0.013 (-2.154**)	-0.011 (-2.612**)
LFFEC	-0.188 (-3.830**)	0.067 (3.011**)	-0.184 (-5.591**)	-0.206 (-4.073**)	0.033 (1.161)
LENIM	0.056 (1.500)	-0.182 (-6.247**)	0.018 (0.723)	0.072 (2.192**)	-0.191 (-3.940**)
LTSE		-0.040 (-1.269)			
LSSE			-0.117 (-2.275**)		
LPSE				0.040 (1.008)	
LUEE					0.078 (0.620)
Adjusted R-squared	0.77	0.78		0.78	0.77
S.E. of regression	0.013	0.013		0.013	0.013

Note: ** represents significance at the 5% critical level.

Table 6a. Interactive effects of education on total renewable energy consumption.

Variable	Model II (SET)	Model III (SES)	Model IV (SEP)	Model V (TEU)
LGDPC	-380.73 (-3.11**3)	-133.96 (-2.157**)	-148.71 (-1.591)	-181.16 (-2.155**)
LFFEC	-0.437 (-1.543)	-0.115 (-0.525)	0.426 (1.301)	0.565 (1.628)
LENIM	2.180 (6.199**)	0.718 (1.990***)	1.730 (5.578**)	2.163 (9.891**)
LTSE	-0.1369 (-1.427)			
LSSE		0.015 (1.174)		
LPSE			-0.255 (-1.728)	
LUEE				-0.123 (-7.135**)
LGDPC*TSE	-0.02 (-3.467**)			
LGDPC*SSE		-00226 (-1.028)	-	
LGDPC*PSE			0.711 (0.771)	
LGDPC*UEE				0.176 (5.641**)
Adjusted R-squared	0.88	0.94		0.89
S.E. of regression	0.156	0.106		0.145
	1.190	0.775		1.383

Note: ** signifies that the coefficients are significant at the 5% critical level.
* stands for multiplication, which signifies interaction between economic growth (LGDPC) and the different measures of educational attainment variables (see Equation 3).

Regarding secondary school education (SSE), economic growth outweighed the effects of education to the point where the combined effect of education and economic growth became negative and inconsequential. The influence of economic growth on primary education was negligible, and both economic growth and primary education individually and collectively are insignificant; therefore, encouraging renewable energy consumption in Nigeria is less dependent on primary education. Alone, and in conjunction with economic growth, only technical education has a substantial impact on renewable energy. The most significant finding of this analysis is that the negative effects of economic growth and postsecondary education became positive when they were combined. This suggests that university education has a significant supporting role in Nigeria's transition from nonrenewable to renewable energy.

In the case of renewable electricity in Nigeria, there was a considerable disparity between the effects of the different levels of education and their effect on economic growth. All educational attainment and results have considerable positive effects on the use of renewable electricity. This is consistent with past cointegration model estimates. Yet, when paired with economic growth, they remained significant but turned negative, confirming the overwhelmingly negative effects of economic growth and income level on the potential of leveraging education to accelerate Nigeria's transition from nonrenewable to renewable energy sources.

Due to the fact that economic growth has considerable moderating effects on the role of education in promoting renewable energy, we evaluated the threshold income level that could increase the effectiveness of educational attainment in Nigeria in encouraging the adoption of renewable energy. The results are presented in Table 7.

Table 6b. Interactive effects of education on renewable electricity energy consumption.

Variable	Model II (SET)	Model III (SES)	Model IV (SEP)	Model V (TEU)
LGDPC	227.37 (6.255**)	118.25 (8.696**)	50.141 (5.763**)	118.50 (13.649**)
LFFEC	0.342 (4.068**)	0.072 (1.508)	-0.119 (-3.907**)	-0.116 (-3.236**)
LENIM	0.041 (0.394)	-0.172 (-2.180**)	0.010 (0.358)	0.106 (4.706**)
LTSE	0.870 (3.053**)			
LSSE		0.267 (9.538**)		
LPSE			0.275 (20.033**)	
LUEE				0.912 (29.683**)
LGDPC*TSE	-0.372 (-2.271**)			
LGDPC*SSE		-0039 (-5.980**)		
LGDPC*PSE			-0018 (-9.185**)	
LGDPC*UEE				-1.101 (-18.925**)
Adjusted R-squared		0.28	0.78	0.70
S.E. of regression		0.023 0.609	0.013 0.175	0.015 0.83

Note: ** signifies that the coefficients are significant at the 5% critical level.
* stands for multiplication, which signifies interaction between economic growth (LGDPC) and different measures of the educational attainment variables (see Equation 3).

Table 7 shows the optimal economic growth necessary to make educational outcomes meaningful for facilitating the transition from nonrenewable to renewable energy. The statistical evidence in Table 7 shows that to significantly encourage the transition to total energy consumption and electrical renewable energy consumption, respectively, the per capita income must increase by at least 7%, and technical education must improve by 2% on average. Thresholds of 7.5% and 3% are required for secondary education, whereas less than 1% and 2% are required for primary education. The use of total renewable energy and renewable electricity must increase by 1% and 9%, respectively, in order to encourage higher education.

Table 7. Computation of threshold values for education and economic growth variables.

Variable	TSE		SSE		PSE		UEE	
	LRNEC	LRNENC	LRNEC	LRNENC	LRNEC	LRNENC	LRNEC	LRNENC
Education variable coefficients (β_1)	0.137	0.81	0.015	0.27	0.26	0.028	0.123	0.912
Interactive terms (β_5)	0.02	0.372	0.002	0.091	0.71	0.018	0.176	0.101
$\overline{LGDPC} = \frac{-\beta_1}{\beta_5}$	6.85	2.17	7.5	2.96	0.36	1.55	0.69	9.02

5. CONCLUSION AND POLICY RECOMMENDATIONS

Using Nigeria-specific data from 1990 to 2021, this research analyzed the influence of education in encouraging the shift from nonrenewable to renewable energy sources. In a model that comprised four measures of education, the second-generation cointegration of FMOLS was used to estimate two proxies of renewable energy consumption on fossil fuels, energy import, and real GDP per capita as controlling variables. The purpose of utilizing several education components was to establish which level of education is most important for the transition to renewable energy. The introduction of fossil fuels is intended to evaluate whether or not fossil fuels play a complementary function or to test the energy mix hypothesis in Nigeria. In addition, the study assesses the moderating effect of education on the influence of economic growth as a driver of energy transition. It determines the required rise in educational enrollment in Nigeria for economic expansion and the transition to renewable energy.

The four variables related to educational outcomes have a favorable and significant effect on the global transition to renewable energy sources. This suggests that education is a crucial factor in achieving Nigeria's renewable energy targets. In contrast to the findings of Sart et al. (2022) and Inglesi-Lotz and Morales (2022), this study indicates that all types of education are equally significant for supporting the shift away from nonrenewable energy consumption in Nigeria. Since renewable energy, unlike traditional energy sources, requires knowledge and technicalities, many renewable energy appliances and technologies may not be adopted without proper education and the ability to read. However, with improved general and technical education and skills, the chances of adopting and utilizing renewable energy may increase, allowing people to ascend to a cleaner energy stratum. Regarding the transition to renewable energy, it was evident that technology and university education are the most important factors that may aid in Nigeria's mandated renewable energy transition. Hence, general education might not be sufficient to achieve the transition to green energy in Nigeria.

It was also established that a minimum level of education enrollment is required to minimize the negative impact of Nigeria's low economic growth on its energy transition. Hence, the paper concludes that although education is essential for the transition from nonrenewable to renewable energy, the type of education matters, and in the case of Nigeria, technical education is the most important factor in promoting the adoption and use of renewable energy. In terms of encouraging energy transition in Nigeria, the change in purchasing power, measured by economic growth, is more essential than education. Yet, attaining a particular level of education helps offset the negative impact of economic expansion and capacity on energy transition. To attain the desired goal of energy transition in Nigeria, a policy aimed at promoting energy transition must be complemented with technical education development initiatives and economic empowerment.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: The corresponding author may provide study data upon reasonable request.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

REFERENCES

Aguirre, M., & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy, 69*, 374-384. https://doi.org/10.1016/j.enpol.2014.02.036

Aïssa, M. S. B., Jebli, M. B., & Youssef, S. B. (2014). Output, renewable energy consumption and trade in Africa. *Energy Policy, 66*, 11-18. https://doi.org/10.1016/j.enpol.2013.11.023

Alam, S., & Butt, M. S. (2002). Causality between energy and economic growth in Pakistan: An application of cointegration and error correction modeling techniques. *Pacific and Asia Journal of Energy, 12*(2), 151-165.

Dees, P., & Auktor, G. (2017). *Renewable energy and economic growth in the MENA region: Empirical evidence and policy implications*. Paper presented at the Conference Contribution, Prepared for the 37th Annual Meeting of the Middle East Economic Association, Chicago, IL, January.

Farabi, A., & Abdullah, A. (2020). Environmental degradation in Indonesia and Malaysia: The effect of energy consumption, economic growth, population, and foreign direct investment. *Journal of Theory and Applied Management, 13*, 160-177. https://doi.org/10.20473/jmtt.v13i2.19483

Farhani, S. (2013). Renewable energy consumption, economic growth and CO2 emissions: Evidence from selected MENA countries. *Energy Economics Letters, 1*(2), 24-41.

Inglesi-Lotz, R., & Morales, L. D. C. C. (2022). *The effect of education on a country's energy consumption: Evidence from developed and developing countries; Working Paper Series 2017; University of pretoria department of economics: Pretoria, South Africa, 2017*. Retrieved from https://www.up.ac.za/media/shared/61/WP/wp_2017_33.zp117672.pdf

IRENA. (2019). *Global energy transformation: A roadmap to 2050, international renewable energy agency*. Retrieved from https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

Kazar, G., & Kazar, A. (2014). The renewable energy production-economic development nexus. *International Journal of Energy Economics and Policy, 4*(2), 312-319. https://doi.org/10.1016/j.renene.2021.07.142

Lasantha, C., & Nawarathna, K. (2022). The simultaneous impact of education and financial development on renewable energy consumption: An investigation of Next-11countries. *Environmental Science and Pollution Research, 29*(56), 85492–85509. https://doi.org/10.1007/s11356-022-21330-7

Lekana, H. C., & Ikiemi, C. B. S. (2021). Effect of energy consumption on human development in the countries of the economic and monetary community of central Africa (EMCCA). *Theoretical Economics Letters, 11*(3), 404-421. https://doi.org/10.4236/tel.2021.113027

Li, F., Dong, S., Xue, L., Liang, Q., & Yang, W. (2011). Energy consumption-economic growth relationship and carbon dioxide emissions in China. *Energy Policy, 39*(2), 568-574. https://doi.org/10.1016/j.enpol.2010.10.025

Mallick, H. (2009). Examining the linkage between energy consumption and economic growth in India. *The Journal of Developing Areas, 43*(1), 249-280. https://doi.org/10.1353/jda.0.0038

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2010). Motivations driving renewable energy in European countries: A panel data approach. *Energy policy, 38*(11), 6877-6885.

Menyah, K., & Wolde-Rufael, Y. (2010). "CO2 emissions, nuclear energy, renewable energy and economic growth in the US". *Energy Policy, 38*(6), 2911-2915.

Moustapha, M. A., Yu, Q., & Danqauh, B. A. (2021). Analyzing the linkage between renewable energy consumption and economic growth in West Africa. *International Energy Journal, 21*(2), 225-234.

Nations, U. (1992). United Nations framework convention on climate change. *Paper Fccc/Informal/84 Ge.05, 62220*(E), 1-25.

Omri, A., Nguyen, D. K., & Rault, C. (2014). Causal interactions between CO2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. *Economic Modelling*, *42*(6), 382-389.

Pfeiffer, B., & Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics*, *40*, 285-296. https://doi.org/10.1016/j.eneco.2013.07.005

Phillips, P., & Moon, H. (1999). Linear regression limit theory for nonstationary panel data. *Econometrica*, *67*(5), 1057-1112. http://dx.doi.org/10.1111/1468-0262.00070

Phillips, P. C. B., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I (1) processes. *The Review of Economic Studies*, *57*(1), 99-125.

Sadorsky, P. (2009). "Renewable energy consumption, CO2 emissions and oil prices in the G7 countries". *Energy Economics*, *31*(3), 456-462.

Sahoo, M., & Sethi, N. (2020). Does remittance inflow stimulate electricity consumption in India? An empirical insight. *South Asian Journal of Business Studies*, *11*(1), 45-66. https://doi.org/10.1108/sajbs-05-2020-0158

Saibu, O. M., & Omoju, O. E. (2016). Macroeconomic determinants of renewable electricity technology adoption in Nigeria. *Economic and Environmental Studies*, *16*(1), 65-83.

Sart, G., Bayar, Y., Sezgin, F. H., & Danilina, M. (2022). Impact of educational attainment on renewable energy use: Evidence from emerging market economies. *Energies*, *15*(7), 1-15. https://doi.org/10.3390/en15072695

Sasmaz, M. U., Sakar, E., Yayla, Y. E., & Akkucuk, U. (2020). The relationship between renewable energy and human development in OECD countries: A panel data analysis. *Sustainability*, *12*(18), 1-16. https://doi.org/10.3390/su12187450

Satrovic, E. (2018). The Human development relies on renewable energy: Evidence from Turkey. *Uemk 2018 Bildiri Özetleri KitabI 18-19 Ekim 2018 Hukuk Fakültesi*, 19-27.

.