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Impact of Educational Attainment on Renewable Energy Use: Evidence from Emerging Market Economies

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Abstract: Renewable energy has become a crucial factor for circular economies, sustainable development, and the environment given the limited non-renewable energy reserves and global environmental degradation mainly resulting from non-renewable energy use. This study explores the effect of educational attainment and economic growth on renewable energy use in a sample of selected emerging markets over the 2000–2018 period through causality and cointegration analyses. Causality analysis points out a significant unidirectional causality from indicators of educational attainment and economic growth to renewable energy use. In other words, educational attainment indicators and economic growth are significant determinants of renewable energy in the short run. Furthermore, the cointegration analysis ascertains a positive influence of indicators of educational attainment and economic growth on renewable energy use in the long run. The findings of both analyses indicate that educational attainment and economic growth have a significant impact on renewable energy use in the short and long term. Therefore, the policies fostering educational attainment can be used as instruments to increase the share of renewable energy use in total energy consumption.

Keywords: educational attainment; economic growth; renewable energy; circular economy; panel causality analysis; panel cointegration analysis

Citation: Sart, G.; Bayar, Y.; Sezgin, F.H.; Danilina, M. Impact of Educational Attainment on Renewable Energy Use: Evidence from Emerging Market Economies. *Energies* **2022**, *15*, 2695. https://doi.org/10.3390/en15072695

Academic Editors: María Ángeles Martín-Lara and Hua Li

Received: 11 March 2022
Accepted: 31 March 2022
Published: 6 April 2022

1. Introduction

The world population, global production in primary, secondary, tertiary, and quaternary sectors of economies, and consumption in these sectors are steadily increasing across the world. As a consequence, energy demand is also going up in direct proportion to the increases in population, production, and consumption. The global energy requirement is already met by non-renewable energy sources to a great extent. The shares of oil, coal, natural gas, and nuclear energy in global primary energy consumption of 2020 were, respectively, 31.2%, 27.2%, 24.7%, and 4.3% [1], although significant contraction in global energy consumption was experienced due to the ongoing COVID-19 pandemic. On the other hand, the share of renewable energy sources in global primary energy consumption was 5.7% in 2020 [1]. The global energy supply increased 2.6 times between 1971 and 2019, but its structure considerably changed. The share of oil decreased from 44% to 31%, the share of coal remained steady with 26.8%, but the share of natural gas increased from 16% to 23% during the 1971–2019 period [2].

Renewable energy sources took second place in world electricity production after coal in 2019, and natural gas followed the renewable energy sources [2]. Furthermore, it is expected that renewable electricity production will be increased and will meet the 95% increases in world power capacity by 2026 [2]. China is the leader at renewable electricity production, with Europe, the United States, and India following China. Furthermore, these developed and emerging economies have also made the highest energy investments in the world [3,4]. Renewable energy production requires high investments, but a dollar spent on wind and solar photovoltaic use requires four times more electricity than 10 years ago due to rapid technological improvements and cost reductions [4].

The world has already met a large part of its energy requirement from non-renewable energy and this trend is not expected to change in the near future. However, decreasing non-renewable energy reserves and environmental concerns about fossil energy consumption have encouraged countries toward clean energy sources because the energy sector is the main source of global emissions and climate change. CO_2 emissions from energy and industry have also increased by 60% since the United Nations Framework Convention on Climate of 1992 [5]. Furthermore, the sustainable development goal of affordable and clean energy by the United Nations General Assembly suggests that the share of renewable energy use in energy consumption should be increased [6]. Renewable energy is also an important component of the circular economy because renewable energy production leads to no waste and raises the provision of limited energy sources [7].

In this context, renewable energy, together with energy efficiency have become the critical factors for decarbonization, sustainable economic growth, and a circular economy. Therefore, researchers and policy-makers have focused on institutional, economic, and social determinants of renewable energy production and in turn institutions, economic freedom and its components, economic growth, real GDP (gross domestic product) per capita, human capital, human development, energy investments, energy dependence, intellectual property rights, urbanization, research & development expenditures, technological development, population growth, trade openness, environment policies, CO_2 emissions, cultural acceptance of renewable energy, and energy saving habits have been documented as the factors underlying renewable energy use and production in the relevant literature [8–15]. Furthermore, energy access is crucial for education, human development, access to information, food security, and provision of basic needs of individuals, and sustainable growth and development [16]. In this regard, renewable energy access is also important for a sustainable environment, economic growth and development, and human development through providing a healthier life [17]. Furthermore, a lower education level is generally associated with lower income and environmental consciousness and less tendency to accept new technologies and in turn reluctance towards renewable energy [18]. On the other hand, renewable energy production needs financing and technological development and in turn higher economic performance, education levels, and human development. Therefore, a reciprocal interaction between educational attainment and renewable development is hereby expected in theoretical terms.

In the article, the effect of educational attainment and economic growth on renewable energy use was investigated in a sample of emerging economies through causality and cointegration tests. On the one hand, emerging economies such as China, India, Brazil, and Russia are driving the global economy; on the other hand, China, Brazil, and India are among the global leaders in producing renewable energy [1]. Therefore, the nexus of educational attainment and renewable energy was analyzed in a sample of emerging market economies. The study intends to make a contribution to the related literature in two ways. First, only a few researchers have investigated the relationship between educational attainment proxied by secondary and/or tertiary school enrollment and renewable energy at panel level without taking the country's specific characteristics into consideration. However, our study investigates the interaction between educational attainment and renewable energy at both country level and panel level, considering county specific characteristics and in turn purposes to contribute to the related literature. Secondly, the empirical studies have generally employed first generation econometric tests, which disregard cross-sectional dependence and heterogeneity. However, we utilize a second generation cointegration test and estimator, which take cross-sectional dependence and heterogeneity into account, as compatible with the dataset's characteristics, and these tests lead us to attain relatively reliable consequences.

The study is formed as follows: the theoretical background and empirical literature about relationship among educational attainment, economic growth, and renewable energy are presented in Section 2. Section 3 explains the dataset and analysis method and Section 4 implements the analysis. The article eventuates in Section 5.

2. Literature Review

Renewable energy is crucial for circular economy, sustainable environment and development. Therefore, a determination of factors underlying the renewable energy is informative for the design of optimal energy policies. In the literature, the researchers have generally investigated the impact of institutions and economic variables such as economic growth, human capital, research and development expenditures, and globalization on renewable energy. However, the impact of educational attainment, one of the main inputs to human capital, human development, and technological innovation and development, which affect economic growth, on renewable energy has been relatively little explored by the researchers as seen in the following literature review.

The scholars investigating the effect of educational attainment on renewable energy production and consumption have mainly revealed the positive influence of educational attainment on renewable energy (e.g., see [18–21]). However, the studies presented in Table 1 have focused on the panel level interaction between education and renewable energy, and none of them have conducted the country level analysis despite the differences in country specific characteristics. Furthermore, we explored the literature about the relationship between human development and renewable energy because educational attainment is a critical input to human development, but the findings of these studies have differed among the countries or country groups depending on the country's specific characteristics [22–27].

Table 1. Literature summary about the nexus between educational attainment/human development and renewable energy use.

Study	Sample; Study Period	Method	Evaluation
Özçiçek ve Ağpak [18]	62 countries; 1990–2014	Pseudo Poisson maximum likelihood method	A positive effect of secondary and tertiary enrollment rate on non-hydro renewable energy was revealed. However, the authors only conducted a panel level analysis.
Mehrara et al. [19]	9 Economic Cooperation Organization countries; 1992–2011	Regression analysis	A positive effect of tertiary school enrollment on renewable energy use was discovered. However, the authors only conducted a panel level analysis.
Gholami et al. [20]	South Asian Association of Regional Cooperation countries; 1995–2015	Westerlund cointegration test and Granger causality test	Human capital index increased the renewable energy use and a unilateral causality from human capital index to renewable energy consumption. However, the authors only estimated the panel cointegration coefficients.

Table 1. *Cont.*

Study	Sample; Study Period	Method	Evaluation
Inglesi-Lotz and Morales [21]	21 countries; 1980–2013	Pedroni cointegration test and Granger causality test	A unilateral causality from secondary education enrollment to primary energy consumption was discovered. However, the authors employed a first generation cointegration test and traditional Granger causality test and did not examine the relationship between education and renewable energy use.
Kazar and Kazar [22]	154 countries; 2005–2010 and 1980–2010	Causality and regression analyses	A bidirectional causality between human development and renewable energy, and a long-run positive effect of human development on renewable energy production was discovered.
Sasmaz et. al. [23]	28 OECD member states; 1990–2017	Second generation cointegration and causality tests	A bidirectional causality between human development and renewable energy and a positive impact of renewable energy on human development in the long run was discovered.
Azam et al. [24]	30 developing countries; 1990–2017	Panel vector autoregressive	A bilateral causality between human development and renewable energy was discovered.
Satrovic [25]	Turkey; 1992–2015	Cointegration and causality analyses	A unidirectional causality from renewable energy to human development was discovered.
Soukiazis et al. [8]	28 OECD members; 2004–2015	Simultaneous equation system approach	Human capital had a positive influence on renewable energy consumption.
Ergun et al. [28]	21 African countries; 1990–2013	Causality and regression analyses	A bilateral causality between human development and renewable energy use, and negative impact of human development on renewable energy use was discovered.
Wang et al. [26]	Pakistan; 1990–2014	Two-stage least square	An insignificant effect of renewable energy on human development was discovered.
Lekana and Ikiemi [27]	Economic and Monetary Community of Central African economies; 1990–2019	Cointegration analysis	An insignificant effect of renewable energy use on human development was discovered.

In this context, Mehrara et al. [19] researched the determinants of renewable energy demand in 9 Economic Cooperation Organization countries for the 1992–2011 period through regression analysis, and their findings revealed that the tertiary school enrollment rate positively affected renewable energy use. On the other hand, Özçiçek ve Ağpak [18] explored the effect of educational attainment proxied by secondary and tertiary enrollment rate on non-hydro renewable energy (that is, renewable energy obtained from biomass, geothermal, solar, and wind, except hydropower) consumption in 62 countries for the 1990–2014 period through the pseudo Poisson maximum likelihood method and obtained a positive effect of both indicators of educational attainment on non-hydro renewable energy use, with the effect increasing in relatively higher education levels. Gholami et al. [20] explored the impact of education, as represented by human capital index and based on schooling years, education returns, and economic growth, on renewable energy use in South Asian Association of Regional Cooperation countries for the 1995–2015 period through a second generation cointegration test and causality analyses, and reached the conclusion that education and economic growth increased the renewable energy use and that there was a unilateral causality from education and economic growth to renewable energy consumption. In other words, education and economic growth had a significant impact on renewable energy use, and both education and economic growth were significant determinants of renewable energy use. Inglesi-Lotz and Morales [21] also explored the relationship between education proxied by secondary education enrollment and primary energy consumption in 10 developed and 11 developing economies for the 1980–2013 period through first generation cointegration and causality tests, and identified a unilateral causality from education to energy consumption.

Some scholars have analyzed the interaction between human development and renewable energy, but their findings have stayed inconclusive. A mutual interaction between human development and renewable energy is expected at theoretical terms, because on the one hand, human development needs energy, and on the other hand renewable energy requires human development [16]. However, the causality between human development and renewable energy use can be varied depending on country-specific characteristics. In this context, Kazar and Kazar [22], Sasmaz et. al. [23], and Azam et al. [24] discovered a bidirectional causality between human development and renewable energy use as compatible with theoretical expectations; however, Satrovic ([25] found a one-way causality from renewable energy to human development. Furthermore, Wang et al. [26] and Lekana and Ikiemi [27] disclosed no significant effects of renewable energy on human development.

Kazar and Kazar [22] investigated the relationship between renewable energy production and human development in a panel of 154 countries for the 2005–2010 period and the 1980–2010 period through causality and regression analyses, and discovered a bidirectional causality between two variables for the 2005–2010 period; however, human development would raise the renewable energy production in the long run. On the other hand, Sasmaz et. al. [23] examined the short- and long-run interaction between human development and renewable energy in 28 OECD (Organisation for Economic Co-operation and Development) countries for the 1990–2017 period through causality and cointegration tests, and found a bidirectional causality between human development and renewable energy in the short run and a positive impact of renewable energy on human development in the long run. Azam et al. [24] also explored the interaction between human development, ICT (information and communication technologies), economic growth, and renewable energy in 30 developing countries for the 1990–2017 period through a PVAR (panel vector autoregressive) approach, and the causality analysis revealed a bilateral causality between human development and renewable energy.

Satrovic [25] researched the interaction between renewable energy and human development in Turkey for 1992–2015 duration via cointegration and causality analyses and revealed a significant one-way causality from renewable energy to human development. On the other hand, Soukiazis et al. [8] investigated the interaction between renewable energy, economic indicators, and pollution emissions in 28 OECD members for the 2004–2015 period via a simultaneous equation system approach, and human capital had a positive influence on renewable energy consumption.

However, Ergun et al. [28] explored the determinants of renewable energy use in 21 African countries over the 1990–2013 period via causality and regression analyses and reached a bilateral causality between human development and renewable energy use, showed a negative impact of human development and economic growth on renewable energy use. Furthermore, Wang et al. [26] discovered that renewable energy did not have a significant impact on human development in Pakistan. Lekana and Ikiemi [27] investigated the effect of energy use on human development in Economic and Monetary Community of Central African economies for the 1990–2019 period via cointegration analysis and discovered an insignificant effect of renewable energy use on human development in the sample.

Lastly, the energy–economic growth nexus has been extensively researched in the related literature, but stayed inconclusive. The four hypotheses on the energy–economic growth nexus are suggested as growth hypothesis (unilateral causality from energy consumption to economic growth), conservation hypothesis (unilateral causality from economic growth to energy consumption), feedback hypothesis (a bidirectional causality between energy consumption and economic growth), and neutrality hypothesis (insignificant causality between energy consumption and economic growth) [8]. However, a consensus has not been reached on these hypotheses given the findings of related empirical literature. Mutumba et al. [29] concluded that growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis accounted for 43.8%, 27.2%, 18.5%, 10.5% of country specific studies, respectively.

3. Data and Method

This study examined the impact of educational attainment and economic growth on renewable energy use in 15 emerging markets through cointegration and causality tests. Renewable energy use was proxied by renewable energy consumption as a percentage of total final energy consumption and obtained from the World Bank [30]. On the other hand, educational attainment was represented by the tertiary school enrollment rate of World Bank [31] and education index of UNDP (United Nations Development Programme) [32]. Tertiary school enrollment rate is the rate of total enrollment to the population of the age group officially corresponding to the tertiary education [30] and education index as calculated as an average of mean years of schooling and expected schooling years [32]. In the selection of tertiary school enrollment, we evaluated that higher education may have a relatively higher impact on economic growth, human capital, technological development, and institutions that have been documented as significant determinants of renewable energy. Furthermore, Mehrara et al. [19] and Özçiçek ve Ağpak [18] also proxied the educational attainment by tertiary education enrollment rate. On the other hand, education index of UNDP [32] was included in the model for the robustness check of the findings. Lastly, economic growth as a control variable included in the econometric model was represented by GDP per capita based on constant 2015 US$ and provided by the World Bank [33]. All series in Table 2 were annual and covered the 2000–2018 period. The logarithmic forms of the series (indicated with LN) were used in the econometric analyses.

Table 2. Dataset description.

Variables	Description	Source
RNW	Renewable energy consumption (% of total final energy consumption)	World Bank [30]
HEDU	School enrollment, tertiary (% gross)	World Bank [31]
EDU	Education index	UNDP [32]
GDP	GDP per capita (constant 2015 US$)	World Bank [33]

The study sample was formed from emerging economies, which are the key drivers of the current global growth and the main energy consumers in the world. In this context, we used the classification of the MSCI (Morgan Stanley Capital International, New York, NY, USA) [34], which evaluates global equity markets and classifies each country as a developed, emerging, frontier, or standalone market. Hence, the study sample consisted of 15 emerging markets (Brazil, Chile, China, Colombia, Czech Republic, Egypt, Greece, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Poland, Russia, except Kuwait, Peru, Philippines, Qatar, Saudi Arabia, South Africa, Taiwan, Thailand, Turkey, and United Arab Emirates) based on the data non-availability.

The descriptive statistics of the dataset are denoted in Table 3. The mean of renewable energy was 17.684% of total final energy use in the sample, but very changeable among the countries. The average of tertiary school enrollment rate was 49.616%, but, similarly, this rate was very changeable from country to country. On other hand, the mean of education index was 0.687 and, relatively, much less changeable. Lastly, the mean of real GDP per capita was USD 9817.696 and the most changeable indicator among the emerging markets. Furthermore, country-level summary characteristics are presented in Table A1 at Appendix A and the distribution of the series at country level can be seen from Table A1.

Table 3. Descriptive statistics for variables.

Characteristic	RNW	HEDU	EDU	GDP
Mean	17.684	49.616	0.687	9817.695
Median	11.376	43.930	0.684	8929.301
Maximum	51.858	142.852	0.893	31,040.66
Minimum	0.6922	7.590	0.379	757.6687
Standard Deviation	14.768	27.167	0.124	6487.550
Skewness	0.774	0.799	−0.241	0.949523
Kurtosis	2.245	3.207	2.058	3.650753

In the empirical analysis part of the article, the steps in Figure 1 were followed. The pre-tests of cross-sectional dependence, heterogeneity, and unit root were firstly applied. Then, cointegration and causality analyses were implemented.

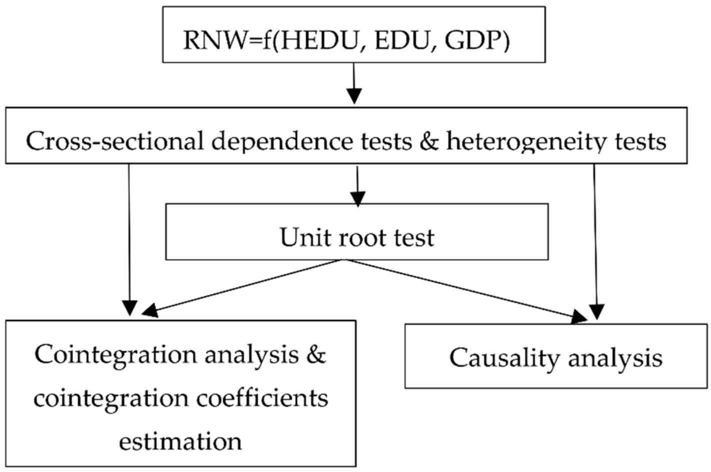

Figure 1. Flowchart of empirical analysis.

The cross-sectional independence means that the countries in the panel are not influenced by any shock to a country in the panel. However, any shock to a country in the panel can generally affect the remaining countries in different ways due to current high trade and financial globalization. Therefore, panel-data models generally exhibit significant cross-section dependence [35]. In this context, the existence of cross-sectional independence was examined via *LM* (Lagrange multipliers), *CD* (cross-section dependence), and $LM_{adj.}$ (bias-adjusted *LM* test) tests, respectively, by Breusch and Pagan [36], Pesaran [37], and Pesaran et al. [38].

LM test statistic is calculated as following:

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \sim \chi_{N(N-1)/2} \tag{1}$$

In the above equation, $\hat{\rho}$ is the sample estimation of pairwise correlation of the residuals. The null hypothesis of the test suggests cross-sectional independence, and the test is used when the time dimension of the dataset is higher than the cross-section dimension of the dataset [37].

CD test is an improved version of *LM* and used with higher *T* and *N* values, and the null hypothesis suggests cross-sectional independence. The test statistic is calculated as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \sim N(0,1) \tag{2}$$

LM and *CD* tests produce the biased results when the group average is zero and the individual average is not zero. The $LM_{adj.}$ test eliminated the bias by adding the variance and mean to the test statistic [38]. The null hypothesis suggests cross-section independence, and the test statistic is calculated as follows:

$$LM_{adj.} = \left(\frac{2}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \left(\frac{(T-K-1)\hat{\rho}_{ij}^2 - \hat{\mu}_{Tij}}{v_{Tij}}\right) \sim N(0,1) \tag{3}$$

In the above equation, $\hat{\mu}_{Tij}$ and v_{Tij} represent the mean and variance, respectively.

The entity of homogeneity, that is, the homogeneity of slope coefficients, was examined with delta tilde tests by Pesaran and Yamagata [39]. The null hypothesis of both tests suggests the entity of homogeneity, and the test statistics of the delta tilde test and adjusted delta tilde test for small samples are calculated as follows:

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\check{S} - k}{\sqrt{2k}}\right) \sim N(0,1) \tag{4}$$

$$\tilde{\Delta}_{adj.} = \sqrt{N}\frac{N^{-1}\check{S} - E\left(\tilde{Z}_{jt}\right)}{\sqrt{Var}\left(\tilde{Z}_{jt}\right)} \sim N(0,1) \tag{5}$$

The cointegration interaction among indicators of educational attainment, economic growth, and renewable energy use was investigated via a Westerlund and Edgerton [40] bootstrap cointegration test by considering the sample size, presence of cross-sectional dependence, and heterogeneity. The Westerlund and Edgerton [40] bootstrap cointegration test, a second generation cointegration test, takes autocorrelation, heteroscedasticity, and cross-sectional dependency into consideration and gives relatively stronger results for small samples. Furthermore, the critical values derived from the bootstrapping process are regarded instead of asymptotic probability values from standard normal distribution, which is very susceptible to serial correlation [40].

Furthermore, the long-run panel and cross-sectional coefficients were estimated by a FMOLS (Fully Modified Ordinary Least Squares) estimator, which corrects the serial correlation and endogeneity bias and considers the heterogeneity, by Pedroni [41]. The FMOLS estimator is an improved version of the ordinary least squares method and corrects the serial correlation and endogeneity bias. The panel FMOLS estimator is as follows:

$$\hat{\beta}_{GFM}^{*} = N^{-1} \sum_{i=``}^{N} \beta_{FM_i}^{*} \tag{6}$$

$\beta_{FM_i}^{*}$ indicates the cross-sectional coefficients in the above equation. Lastly, the causal connection between education indicators, economic growth, and renewable energy use was investigated by a Dumitrescu and Hurlin [42] causality test, which takes heterogeneity into consideration and generated robust findings under cross-sectional dependence.

4. Results and Discussion

In the empirical analysis part of the article, pre-tests of cross-sectional dependence and heterogeneity to specify the appropriate tests of unit root, cointegration, and causality were firstly investigated. In this context, the existence of cross-sectional independence was examined via *LM*, *CD*, and $LM_{adj.}$ (bias-adjusted *LM* test) tests, respectively, by Breusch and Pagan [36], Pesaran [37], and Pesaran et al. [38], and the tests' consequences were denoted in Table 4. The null hypothesis (there exists cross-sectional independence) was declined, and the entity of cross-sectional dependence was thereby reached.

Table 4. Cross-sectional dependence tests' results.

Test	Test Statistic	Probability Value
LM	212.1	0.000
CD *	13.22	0.000
$LM_{adj.}$ *	31.92	0.000

* two-sided test.

The entity of homogeneity was examined with delta tilde tests by Pesaran and Yamagata [39], and both tests' consequences were denoted in Table 5. The null hypothesis (There exists homogeneity) was declined, and the entity of heterogeneity was thereby reached.

Table 5. Homogeneity tests' results.

Test	Test Statistic	Probability Value
$\tilde{\Delta}$	15.224	0.000
$\tilde{\Delta}_{adj.}$	19.304	0.000

$\tilde{\Delta}\tilde{\Delta}_{adj.}$ The entity of unit root in the series of LNRNW, LNHEDU, LNEDU, and LNGDP was examined with CIPS (Cross-Sectional IPS) [43] unit root test via a Pesaran [44] test in view of cross-sectional dependence, and the unit root test consequences were denoted in Table 6. The test consequences indicated that the variables of LNRNW, LNHEDU, LNEDU, and LNGDP were I (1).

Table 6. CIPS unit root test results.

Variables	Level		First Differences	
	Constant	Constant + Trend	Constant	Constant + Trend
LNRNW	−1.286	−1.317	−7.647 **	−8.124 **
LNHEDU	−1.534	−1.631	−9.215 **	−9.519 **
LNEDU	−1.289	−1.305	−8.204 **	−8.662 **
LNGDP	−1.411	−1.508	−9.338 **	−9.501 **

** It is significant at 5% significance level.

The cointegration interaction between indicators of educational attainment, economic growth, and renewable energy was investigated by means of a Westerlund and Edgerton [40] bootstrap cointegration test that took sample size and cross-sectional dependency into consideration, and the cointegration test consequences are depicted Table 7. The null hypothesis (there exists a cointegration among indicators of educational attainment, economic growth, and renewable energy use) was accepted and a significant cointegration interaction among four variables was thereby revealed.

Table 7. Bootstrap cointegration test results.

Constant			Constant + Trend		
Test Statistic	Asymptotic p-Value	Bootstrap p-Value	Test Statistic	Asymptotic p-Value	Bootstrap p-Value
9.174	0.315	0.439	10.452	0.387	0.482

Note: Bootstrap critical values were generated from 10.000 repetitions, and asymptotic probability values were procured from standard normal distribution.

The cointegration coefficients were estimated by FMOLS estimator and the estimations were depicted in Table 8. The panel cointegration coefficients pointed out that indicators of educational attainment and economic growth had a positive effect on renewable energy use. The cross-sectional cointegration coefficients also disclosed that tertiary school enrollment positively influenced the renewable energy use in all countries except Colombia, Egypt, and Indonesia, and that education index also positively influenced the renewable energy use in all countries except Indonesia and Malaysia. Lastly, economic growth positively influenced the renewable energy use in all countries in the sample. Furthermore, the panel cointegration coefficients indicated that education index had the largest impact on renewable energy use in the long run.

Table 8. Estimation results of cointegration coefficients.

Countries	LNHEDU	LNEDU	LNGPD
Brazil	0.183 **	0.213 **	0.198 **
Chile	0.167 **	0.204 **	0.193 **
China	0.154 **	0.137 **	0.187 **
Colombia	0.160	0.218 **	0.134 **
Czech Republic	0.179 **	0.240 **	0.181 **
Egypt	0.142	0.138 **	0.156 **
Greece	0.176 **	0.210 **	0.162 **
Hungary	0.168 **	0.231 **	0.142 **
India	0.130 **	0.116 **	0.139 **
Indonesia	0.135	0.154	0.143 **
Korea	0.186 **	0.243 **	0.201 **
Malaysia	0.135 **	0.125	0.136 **
Mexico	0.151 **	0.143 **	0.148 **
Poland	0.179 **	0.253 **	0.209 **
Russia	0.190 **	0.261 **	0.212 **
Panel	0.164 **	0.204 **	0.172 **

** it is significant at 5% significance level.

The main factors underlying renewable energy use and energy mix have been documented as economic growth, real GDP per person, human capital and development, technological development, and institutional quality. The educational attainment has been theoretically and empirically suggested as a significant determinant of economic growth and development, human capital, innovation, and technological development, which are also significant determinants of renewable energy consumption [45–50]. Therefore, educational attainment is also theoretically expected to influence the renewable energy use through these channels.

In this context, educational attainment can positively influence the renewable energy use via the supply and demand channels mentioned above. Technological development, financing, and human capital level are critical factors for renewable energy production at the supply side, and positive improvements in human capital, technological development, and financing can foster the renewable energy production [18]. In addition to this, environmental awareness and human capital highly dependent on educational attainment are the significant factors underlying renewable energy use at the demand side [51]. In the empirical literature, only a few scholars have investigated the effect of educational attainment on renewable energy consumption and reached a positive effect of educational attainment and human development on renewable energy use in parallel with the theoretical expectations [8,18–21]. However, Ergun et al. [28] discovered that the negative impact of human development on renewable energy use mainly resulted from the low economic development of the countries in the sample.

China, Brazil, India, Greece, Chile, Indonesia, Colombia, Czechia, and Mexico, respectively, raised their rates of tertiary school enrollment by 566.689%, 209.043%, 195.103%, 181.292%, 156.941%, 144.078%, 125.900%, 124.944%, and 102.639 during the study period, and similarly considerable improvements were achieved in the education index [31,32].

Therefore, considerable improvements in educational attainment also made a significant contribution to renewable energy use in harmony with the relevant theoretical and empirical findings. On the other hand, the positive effect of economic growth on renewable energy supported the conservation hypothesis, which suggests a unidirectional causality from economic growth to energy consumption. In other words, economic growth had a significant impact on renewable energy use and, in turn, energy consumption was determined by economic growth. Therefore, energy conservation policies would not have a significant impact on economic growth [8].

The causality among indicators of educational attainment, economic growth, and renewable energy was investigated by means of a Dumitrescu and Hurlin [42] causality test, and the causality test consequences are depicted in Table 9. The causality analysis pointed out a unilateral causality from both indicators of educational attainment and economic growth to renewable energy use. In other words, educational attainment, and economic growth were also found to be significant determinants of renewable energy use in the short run, but renewable energy use had an insignificant effect on these variables.

Table 9. Causality test results.

Null Hypothesis	Test	Test Statistics	Probability Value
D(LNHEDU) $\nrightarrow$ D(LNRNW)	W^{Hnc}	6.745	0.000
	Z^{Hnc}	6.916	0.000
	Ztild	7.131	0.000
D(LBRNW) $\nrightarrow$ D(LNHEDU)	W^{Hnc}	2.780	0.140
	Z^{Hnc}	3.112	0.152
	Ztild	3.245	0.128
D(LNEDU) $\nrightarrow$ D(LNRNW)	W^{Hnc}	8.505	0.000
	Z^{Hnc}	8.874	0.000
	Ztild	9.015	0.000
D(LBRNW) $\nrightarrow$ D(LNEDU)	W^{Hnc}	1.842	0.205
	Z^{Hnc}	1.905	0.319
	Ztild	2.131	0.250
D(LNGDP) $\nrightarrow$ D(LNRNW)	W^{Hnc}	7.438	0.000
	Z^{Hnc}	8.113	0.000
	Ztild	8.239	0.000
D(LNRNW) $\nrightarrow$ D(LNGDP)	W^{Hnc}	2.673	0.124
	Z^{Hnc}	2.982	0.167
	Ztild	3.104	0.155

Hnc: Homogenous Non-Causality.

The findings of the article about causality interaction between educational attainment and renewable energy use were found to be similar with the findings of Inglesi-Lotz and Morales [21] and Gholami et al. [20].

However, the studies about the interaction between human development, including life expectancy index, education index, and gross national income index and renewable energy use, have reached different conclusions. Kazar and Kazar [22], Sasmaz et. al. [23], Azam et al. [24], and Ergun et al. [28] discovered a bidirectional causality between human development and renewable energy use, and Satrovic ([25] found a one-way causality from renewable energy to human development. On the other hand, Wang et al. [26] and Lekana and Ikiemi [27] disclosed no significant effects of renewable energy on human development. The contradiction among the findings by the researchers can be substantially credited to the different nature of the variables and the countries' respective economic development levels.

5. Conclusions and Policy Implications

The globalized economy has been dependent on non-renewable energy sources for a long time and changes in this trend are not expected in the short run. However, global environmental degradation, limited non-renewable energy sources, and energy security have galvanized the countries into improving their capacity for renewable energy production. Renewable energy has become a crucial factor for circular economies, sustainable development, and the environment. Therefore, many researchers have generally researched the determinants of renewable energy production and consumption. In this article, we investigated the effect of educational attainment and economic growth on renewable energy use in emerging market economies such as China, India, Brazil, and Russia, including the drivers of global economic growth and renewable energy production via causality and cointegration tests, which are compatible with the dataset's characteristics. However, the availability of renewable energy use and tertiary school enrollment data led us to limit the sample size to 15 countries and the study period to the years 2000–2018.

The following consequences were obtained from causality and cointegration analyses:

- The causality analysis pointed out a unidirectional causality from indicators of educational attainment and economic growth to renewable energy use.
- In other words, educational attainment had a significant effect on renewable energy use in the short run.
- The cointegration analysis discovered a positive influence of indicators of educational attainment and economic growth on renewable energy use in the long run.
- Conservation hypothesis was found to be valid for the sample given the findings of causality and cointegration tests. Therefore, policies of energy conservation would have an insignificant impact on economic growth.
- Educational attainment is a significant instrument for renewable energy use through fostering innovation, technological development, economic growth, and institutional and social development in the long run.
- Educational policies fostering the educational attainment will also make a contribution to the sustainable environment and development by increasing the renewable energy in the long run.
- The positive impact of educational attainment on renewable energy use can be credited to various factors, such as innovation, technological development, economic growth, and institutional and social development. In this context, future studies can analyze the interaction between educational attainment and renewable energy use by decomposing the aforementioned effects of educational attainment.

Author Contributions: The authors contributed equally to this paper. G.S., Y.B., F.H.S. and M.D. determined the context of the paper and empirical analyses and reviewed the related theoreretical and empirical literature. G.S., Y.B., F.H.S. and M.D. conducted the econometric analyses, discussed the findings, and made the inferences. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS (accessed on 3 January 2022), hdr.undp.org/en/data (accessed on 5 January 2022), https://data.worldbank.org/indicator/SE.TER.ENRR (accessed on 3 January 2022), https://data.worldbank.org/indicator/NY.GDP.PCAP.KD (accessed on 3 January 2022), and http://hdr.undp.org/en/data (accessed on 3 January 2022).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Country summary characteristics.

Country	Variables	Mean	Std. Deviation	Minimum	Maximum
Brazil	RNW	45.068	2.138	41.44	49.04
	HEDU	36.504	12.624	17.23	53.26
	EDU	0.627	0.039	0.58	0.69
	GDP	8073.58	870.081	6787.68	9247.59
Chile	RNW	29.481	2.993	24.11	33.07
	HEDU	63.183	19.247	35.38	90.90
	EDU	0.744	0.0439	0.66	0.81
	GDP	11,568.969	1808.875	8685.32	13,901.02
China	RNW	16.565	6.1419	11.34	29.60
	HEDU	27.015	13.823	7.59	50.60
	EDU	0.579	0.058	0.48	0.65
	GDP	5412.692	2440.506	2193.89	9688.47
Colombia	RNW	30.0963	1.4771	27.24	32.53
	HEDU	39.4581	11.3879	24.49	56.43
	EDU	0.610	0.053	0.53	0.68
	GDP	5119.892	856.891	3961.93	6271.88
Czechia	RNW	10.521	3.393	5.94	14.86
	HEDU	54.068	13.238	28.35	65.67
	EDU	0.838	0.0480	0.74	0.89
	GDP	16,036.891	2119.032	12,312.50	19,685.49
Egypt	RNW	5.904	0.941	4.74	7.82
	HEDU	30.959	2.933	26.82	38.90
	EDU	0.5425	0.047	0.47	0.61
	GDP	3216.751	407.024	2610.48	3831.20
Greece	RNW	11.466	4.141	7.11	17.86
	HEDU	98.524	27.366	50.78	142.85
	EDU	0.778	0.050	0.67	0.83
	GDP	20,291.651	2243.880	17,762.18	24,081.66
Hungary	RNW	10.893	4.599	4.63	17.18
	HEDU	55.635	9.797	35.94	68.28
	EDU	0.799	0.029	0.74	0.83
	GDP	11,518.595	1362.843	8967.37	14,368.64
India	RNW	42.488	6.932	31.69	51.86
	HEDU	17.921	7.206	9.51	28.06
	EDU	0.471	0.059	0.38	0.56
	GDP	1223.046	362.231	757.67	1915.44
Indonesia	RNW	35.455	7.717	20.86	45.62
	HEDU	24.034	8.135	14.18	36.44
	EDU	0.581	0.039	0.52	0.64
	GDP	2677.459	603.356	1867.55	3732.87
Korea	RNW	1.537	0.865	0.69	3.18
	HEDU	93.646	8.195	76.66	104.28
	EDU	0.842	0.027	0.79	0.87
	GDP	24,280.313	4363.833	16,992.48	31,040.66
Malaysia	RNW	3.3627	0.966	1.96	5.31
	HEDU	34.975	7.026	25.00	46.76
	EDU	0.666	0.044	0.61	0.72
	GDP	8312.314	1492.009	6286.13	11,067.85

Table A1. *Cont.*

Country	Variables	Mean	Std. Deviation	Minimum	Maximum
Mexico	RNW	9.846	0.829	8.97	12.17
	HEDU	28.227	6.193	20.49	41.52
	EDU	0.627	0.045	0.54	0.69
	GDP	9137.895	430.895	8568.62	9945.78
Poland	RNW	9.175	1.931	6.93	11.87
	HEDU	66.085	6.906	49.67	74.76
	EDU	0.825	0.027	0.78	0.87
	GDP	10,396.778	2186.146	7356.78	14,332.92
Russia	RNW	3.410	0.165	3.18	3.67
	HEDU	74.010	6.933	55.80	84.58
	EDU	0.777	0.028	0.72	0.82
	GDP	9998.596	1822.477	6491.07	11,875.73

References

1. BP. *Statistical Review of World Energy 2021 (70th Edition)*; BP: London, UK, 2021. Available online: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf (accessed on 3 January 2022).
2. IEA. World Energy Balances: Overview 2021. Available online: https://www.iea.org/reports/world-energy-balances-overview (accessed on 3 January 2022).
3. IEA. Renewables 2021. Available online: https://www.iea.org/reports/renewables-2021 (accessed on 3 January 2022).
4. IEA. *World Energy Investment 2021*; IEA: Paris, France, 2021; Available online: https://iea.blob.core.windows.net/assets/5e6b3821-bb8f-4df4-a88b-e891cd8251e3/WorldEnergyInvestment2021.pdf (accessed on 3 January 2022).
5. IEA. Net Zero by 2050: A Roadmap for the Global Energy Sector. Available online: https://www.iea.org/reports/net-zero-by-2050 (accessed on 5 January 2022).
6. United Nations. Envision2030 Goal 7: Affordable and Clean Energy 2022. Available online: https://www.un.org/development/desa/disabilities/envision2030-goal7.html (accessed on 5 January 2022).
7. Majeed, M.T.; Luni, T. Renewable Energy, Circular Economy Indicators and Environmental Quality: A Global Evidence of 131 Countries with Heterogeneous Income Groups. *Pak. J. Commer. Soc. Sci.* **2020**, *14*, 866–912.
8. Soukiazis, E.; Proenca, S.; Cerqueira, P.A. The Interconnections between Renewable Energy, Economic Development and Environmental Pollution: A Simultaneous Equation System Approach. *Energy J.* **2019**, *40*, 1–23. [CrossRef]
9. Gozgor, G.; Mahalik, M.K.; Demir, E.; Padhan, H. The Impact of Economic Globalization on Renewable Energy in the OECD Countries. *Energy Policy* **2020**, *139*, 111365. [CrossRef]
10. Przychodzen, W.; Przychodzen, J. Determinants of Renewable Energy Production in Transition Economies: A Panel Data Approach. *Energy* **2020**, *191*, 116583. [CrossRef]
11. Amoah, A.; Kwablah, E.; Korle, K.; Offei, D. Renewable Energy Consumption in Africa: The Role of Economic Well-being and Economic Freedom. *Energy Sustain. Soc.* **2020**, *10*, 32. [CrossRef]
12. Bayale, N.; Ali, E.; Tchagnao, A.F.; Nakumuryango, A. Determinants of Renewable Energy Production in WAEMU Countries: New Empirical Insights and Policy Implications. *Int. J. Green Energy* **2021**, *18*, 602–614. [CrossRef]
13. Tee, W.-S.; Chin, L.; Abdul-Rahim, A.S. Determinants of Renewable Energy Production: Do Intellectual Property Rights Matter? *Energies* **2021**, *14*, 5707. [CrossRef]
14. Bayar, Y.; Sasmaz, M.U.; Ozkaya, M.H. Impact of Trade and Financial Globalization on Renewable Energy in EU Transition Economies: A Bootstrap Panel Granger Causality Test. *Energies* **2021**, *14*, 19. [CrossRef]
15. Mikalauskas, A.; Mikalauskienė, A. Cultural Acceptance Differences of Renewable Energy Technologies. *Int. J. Cult. Hist.* **2017**, *3*, 270–274. [CrossRef]
16. UNDP. *Sustainable Energy and Human Development in Europe and the CIS*; United Nations Development Programme: New York, NY, USA, 2014.
17. Azam, A.; Rafiq, M.; Shafique, M.; Ateeq, M.; Yuan, J. Investigating the Impact of Renewable Electricity Consumption on Sustainable Economic Development: A Panel ARDL Approach. *Int. J. Green Energy* **2021**, *18*, 1185–1192. [CrossRef]
18. Özçiçek, Ö.; Ağpak, F. The Role of Education on Renewable Energy Use: Evidence from Poisson Pseudo Maximum Likelihood Estimations. *J. Bus. Econ. Policy* **2017**, *4*, 49–61.
19. Mehrara, M.; Rezaei, S.; Davoud, H.R. Determinants of Renewable Energy Consumption among ECO Countries: Based on Bayesian Model Averaging and Weighted-Average Least Square. *Int. Lett. Soc. Humanist. Sci.* **2015**, *54*, 96–109. [CrossRef]
20. Gholami, J.; Villanthenkodath, M.A.; Velan, N. Can Educational Attainment Promote Renewable Energy Consumption? Evidence from Heterogeneous Panel Models. *Int. J. Energy Sect. Manag.* **2022**. [CrossRef]

21. Inglesi-Lotz, R.; Morales, L.D.C.C. *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. Available online: https://www.up.ac.za/media/shared/61/WP/wp_2017_33.zp117672.pdf (accessed on 8 January 2022).
22. Kazar, G.; Kazar, A. The renewable energy production-economic development nexus. *Int. J. Energy Econ. Policy* **2014**, *4*, 312–319.
23. Sasmaz, M.U.; Sakar, E.; Yayla, Y.E.; Akkucuk, U. The Relationship between Renewable Energy and Human Development in OECD Countries: A Panel Data Analysis. *Sustainability* **2020**, *12*, 7450. [CrossRef]
24. Azam, A.; Rafiq, M.; Shafique, M.; Yuan, J.; Salem, S. Human Development Index, ICT, and Renewable Energy-Growth Nexus for Sustainable Development: A Novel PVAR Analysis. *Front. Energy Res.* **2021**, *9*, 760758. [CrossRef]
25. Satrovic, E. The human development relies on renewable energy: Evidence from Turkey. In Proceedings of the 3rd International Energy & Engineering, Book of Proceedings, Gaziantep, Turkey, 19–27 October 2018.
26. Wang, Z.; Danish, Z.B.; Wang, B. Renewable energy consumption, economic growth, and human development index in Pakistan: Evidence form a simultaneous equation model. *J. Clean. Prod.* **2018**, *184*, 1081–1090. [CrossRef]
27. Lekana, H.C.; Ikiemi, C.B.S. Effect of Energy Consumption on Human Development in the Countries of the Economic and Monetary Community of Central Africa (EMCCA). *Theor. Econ. Lett.* **2021**, *11*, 404–421. [CrossRef]
28. Ergun, S.J.; Owusu, P.A.; Rivas, M.F. Determinants of Renewable Energy Consumption in Africa. *Environ. Sci. Pollut. Res.* **2019**, *26*, 15390–15405. [CrossRef]
29. Mutumba, G.S.; Odongo, T.; Okurut, N.F.; Bagire, V. A Survey of Literature on Energy Consumption and Economic Growth. *Energy Rep.* **2021**, *7*, 9150–9239. [CrossRef]
30. World Bank. Renewable Energy Consumption (% of Total Final Energy Consumption) 2022. Available online: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS (accessed on 3 January 2022).
31. World Bank. School Enrollment, Tertiary (% Gross) 2022. Available online: https://data.worldbank.org/indicator/SE.TER.ENRR (accessed on 3 January 2022).
32. UNDP. Human Development Data Center 2022. Available online: http://hdr.undp.org/en/data (accessed on 3 January 2022).
33. World Bank. GDP per Capita (Constant 2015 US$) 2022. Available online: https://data.worldbank.org/indicator/NY.GDP.PCAP.KD (accessed on 3 January 2022).
34. MSCI. Emerging Markets 2022. Available online: https://www.msci.com/our-solutions/indexes/emerging-markets (accessed on 3 January 2022).
35. De Hoyos, R.E.; Sarafidis, V. Testing for Cross-sectional Dependence in Panel-data Models. *Stata J.* **2006**, *6*, 482–496.
36. Breusch, T.S.; Pagan, A.R. The Lagrange Multiplier Test and Its Applications to Model Specification Tests in Econometrics. *Rev. Econ. Stud.* **1980**, *47*, 239–253. [CrossRef]
37. Pesaran, M.H. *General Diagnostic Tests for Cross-Section Dependence in Panels*; Working Paper, CWPE 0435; University of Cambridge: Cambridge, UK, 2004.
38. Pesaran, M.H.; Ullah, A.; Yamagata, T.A. A Bias-Adjusted LM Test of Error Cross-section Independence. *Econom. J.* **2008**, *11*, 105–127. [CrossRef]
39. Pesaran, M.H.; Yamagata, T. Testing Slope Homogeneity in Large Panels. *J. Econom.* **2008**, *142*, 50–93. [CrossRef]
40. Westerlund, J.; Edgerton, D.L. A Panel Bootstrap Cointegration Test. *Econ. Lett.* **2007**, *97*, 185–190. [CrossRef]
41. Pedroni, P. Fully-Modified OLS for Heterogeneous Cointegrated Panels. *Adv. Econom.* **2000**, *15*, 93–130.
42. Dumitrescu, E.I.; Hurlin, C. Testing for Granger Non-causality in Heterogeneous Panels. *Econ. Model.* **2012**, *29*, 1450–1460. [CrossRef]
43. Im, K.S.; Pesaran, M.H.; Shin, Y. Testing for unit roots in heterogeneous panels. *J. Econom.* **2003**, *115*, 53–74. [CrossRef]
44. Pesaran, M.H. A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econom.* **2007**, *22*, 265–312. [CrossRef]
45. Barro, R.J. Economic Growth in a Cross section of Countries. *Q. J. Econ.* **1991**, *106*, 407–443. [CrossRef]
46. Barro, R.J.; Lee, J.W. Education Matters. In *Global Schooling Gains from the 19th to the 21st Century*; Oxford University Press: Oxford, UK, 2015.
47. Hanushek, E.A.; Woessmann, L. Education, Knowledge Capital, and Economic Growth. In *The Economics of Education*; Bradley, S., Green, C., Eds.; Academic Press: London, UK, 2020; pp. 171–182.
48. Findler, F.; Schönherr, N.; Lozano, R.; Reider, D.; Martinuzzi, A. The Impacts of Higher Education Institutions on Sustainable Development: A Review and Conceptualization. *Int. J. Sustain. High. Educ.* **2019**, *20*, 23–38. [CrossRef]
49. Goczek, Ł.; Witkowska, E.; Witkowski, B. How Does Education Quality Affect Economic Growth? *Sustainability* **2021**, *13*, 6437. [CrossRef]
50. Etzkowitz, H. *The Triple Helix: University-Industry-Government Innovation in Action*; Routledge: New York, NY, USA, 2008.
51. Aguirre, M.; Ibikunle, G. Determinants of Renewable Energy Growth: A Global Sample Analysis. *Energy Policy* **2014**, *69*, 374–384. [CrossRef]