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RESEARCH ARTICLE

Does energy conversion contribute to economic development in emerging and growth leading economies (EAGLE's): evidence from panel ARDL approach

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Abstract
Energy is an essential indication of productivity, usage, and nation-building in the development context. However, energy diversity that emphasizes renewables is still vital for economic development in emerging nations. This study examines the impact of renewable energy on economic development in emerging and growth-leading economies (EAGLE's) from 1980 to 2019. The econometric procedure used in this study is pooled mean group regression/Panel ARDL approach. The study's results support the growth-conservation theory and demonstrate that wealth creation is not dependent entirely on fossil fuels and that other energy sources may also be used. There is a positive association between renewable energy production and consumption and economic development in EAGLE countries. For the overall sample selected, the association between the long run and short is positive and significant, whereas individual analysis for each country provided mixed results. In the short run, the association between renewable energy consumption and economic development for Bangladesh, India, Indonesia, Mexico, and Philippines is negative. While in production, most countries showed positive and significant results except Brazil, Indonesia, Mexico, and Russia. The result of this study will help policy makers from the selected countries towards the use of renewable energy production and consumption, its importance and contribution to the economic development of these countries. However, some countries showed a negative relationship particularly Russian economy is rich in natural resources (oil, natural gas). While the remaining countries that showed negative relationship have number of problems associated with renewable energy consumption and production. This study refers the attention of policy makers from developing countries to consider the potential impact of renewable energy for the economic development. Energy transition can also contribute to the environmental protection and the reduction of greenhouse gases.

Keywords Economics development · Renewable energy · EAGLE's · ARDL

Abbreviations

GDP	Gross domestic product
NRE	Non-renewable energy
RE	Renewable energy
EAGLE's	Emerging and growth leading economies
ARDL	Autoregressive distributed lag

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Introduction

Energy has generally been a critical factor in economic development, with traditional energy consumption increasing for many years (Apergis and Payne 2009). However, since the start of the century, nations have faced a variety of energy-related problems around the world, and the dependence on non-renewable energy sources has led to severe challenges on a global scale (Owusu and Asumadu-Sarkodie 2016).

Countries may also explore renewable energy sources in place of primary energy sources to boost economic development if the "growth hypothesis" and "feedback hypothesis" are true. For example, (Bhattacharya et al. 2016) for 38 main renewable energy consuming countries; OECD countries; (Inglesi-Lotz 2016); the Black Sea and Balkan countries (Koçak and Şarkgüneşi 2017; Lu 2017); for BRICS countries; and (Zeb et al. 2014) for South Asian Association for Regional Cooperation (SAARC) countries. This provides enlargement to a current group of literature on the association between renewable energy and economic development. It is now universally acknowledged that using more traditional energy sources like coal, oil, and petroleum to generate economic growth is linked to serious environmental deterioration that impacts both the environment and public health. However, emerging nations perceive limitations upon carbon-intensive energy only as destructive to development-oriented efforts (Edenhofer et al. 2011). Therefore, industrial governments are compelled to design and fund programs to address climate change that is predominantly caused by industries. These issues compelled organizations and global communities to look for conventional energy options. Furthermore, experts point out that using cleaner energy may actively reduce carbon emissions and protect the environment (Ertugrul Yildirim 2014). Therefore, a substantial body of research explores the relationship between complex energy (EC) and development. Many academics have investigated the dynamic relationship between pure energy and growth for different nations using different approaches and local panel data sets and reported varied empirical data. For instance, some researchers, among several others, show a positive correlation between energy usage (whether it comes from renewable sources or not) and economic development. However, other researchers find a link between the consumption of energy and economic development that is negative. Numerous studies have shown that greater energy intensity, or higher energy use, hurts economic progress. Some research shows a neutral relationship between economic development and energy consumption between positive and negative effects, indicating that neither increased nor decreased energy consumption affects economic development, contrary to what other research has shown. Four basic hypotheses, including neutrality, conservation, growth, and feedback, may be used to classify the varied empirical data that analyze the relationship between both energy and economy. According to the neutrality hypothesis, there is no direct relationship between energy and economic growth; hence, changes in the energy and economical portfolio's fundamental composition do not affect their respective development trajectories (Apergis and Payne 2009). The conservation hypothesis establishes a causal relationship between growth and energy, demonstrating that adopting energy-saving management programs has no economic impact (Jakovac 2018). The growth hypothesis highlights the direct relationship between growth and energy. Therefore, reducing energy usage will hinder economic growth (Ertuğrul Yildirim et al. 2012). In light of economic development and energy security, the economic institutionalization and energy strategies aimed at limiting energy use, economic growth, or both may reverse.

The feedback hypothesis suggests a symbiotic association between energy and economic growth. The lack of agreement on the cause-and-effect link between energy and economic growth points to a void in the literature that calls for ongoing research to support these conclusions (Ayres 2001). These contradictory studies indicate an ongoing discussion in which more research is welcome. Disregarding the effects of utilizing conventional energy for economic progress is impossible. From a methodological point of view, we employ a panel ARDL approach in contrast to previous research. The econometric analysis of ARDL is considered one of the most adaptable approaches, especially when regime transitions and shocks influence the research context. The latter alters the energy-growth models' covariate evolution or energy consumption pattern.

Additionally, the ARDL approach is particularly appealing, adaptable, and flexible due to its ability to accept lags in variables. Studies conducted before the development of ARDL utilized cross-sectional analysis using the panel data setup, which was especially pertinent for the energy-growth nexus. This meant that the countries represented in those samples were not substantially homogenous regarding their degree of economic growth (Odhiambo 2009). Results from this research were of little relevance for policy-making unless they were country-specific. In addition, the ARDL technique eliminates residual correlation. It lessens the endogeneity problem by producing unbiased estimates and accurate t-statistics, independent of whether the regressors are endogenous (Ali et al. 2016). When structural breaks are considered, the research yields contradictory findings for the sample of rising nations.

First, even once structural breakdowns are considered, most sample nations do not exhibit a clear causal link between energy use and economic development (Waheed et al. 2019). This result demonstrates the predominance of the neutrality hypothesis and that energy consumption and economic development are not dependent on one another. Second, the study discovered a significant causal association between GDP and RE demand in six rising nations, including Brazil, Thailand, Pakistan, Mexico, and Indonesia. This finding confirms the conservation hypothesis. On the other hand, Turkey, encourage the growth theory since these countries have a clear causal link between RE and GDP. Overall, the results of this research are consistent with earlier studies that identified unidirectional causal linkages in EAGLE's countries. This study varies from Kahia et al. (2017), and other studies which shows a causal link between energy sources and economic development in both directions, suggesting the possibility of energy sources being substituted to increase economic development. According to Bashir et al. (2023), the global energy industry is one of the most adversely impacted sectors since the mechanisms governing energy prices, demand for energy, and supply have all displayed significant ambiguity as a result of these exceptional economic and social shifts. To better understand how the industrial sector will be able to manage energy consumption in the post-pandemic future, we present a quick summary of demand, supply, and price structure of energy products and policy mechanisms. This study attempted to check the relationship between renewable energy consumption and renewable energy production in EAGLE's countries. We conclude that the current analysis makes a substantial contribution to the literature, presents significant variation among rising nations. Recent years have seen an uptick in the amount of empirical research (Apergis and Payne 2010, 2011; Omri et al. 2015; Pao et al. 2014; Salim et al. 2014) that uses the above testable hypothesis to understand better the connection between renewable energy and economic development. The findings of these studies vary significantly based on the chosen samples, used variables, and quantitative research methodologies.

Theoretical background

Growth hypothesis

Bhattacharya et al. (2016) The use of renewable energy had a "substantial positive influence" on long-term economic growth in 57% of the nations they chose, based on panel estimate approaches for the 38 top renewable energy-generating countries for the years 1990–2012. This means that the usage of renewable energy drives economic growth and supports the growth theory. This is consistent with the (Ito 2017) findings. He used conventional and dynamic OLS estimates on a sample of 42 developing nations from 1980 to 2009. He discovered that, over the long term, the use of renewable energy boosted economic development. Inglesi-Lotz (2016) used the Pedroni co-integration approach on a sample of 34 OECD nations between 1990 and 2010 in different research. Additionally, Omri et al. panel's data model for 17 industrialized and developing nations from 1990 to 2011 uses simultaneous dynamic equations. According to this study, Sweden, the Netherlands, India, Hungary, and Japan all support the growth theory. Different research (Pao et al. 2014) used a Vector Error Correction model to examine the Brazilian economy from 1980 to 2010. They discovered a one-way causal relationship between the use of renewable energy and economic development. In addition, (Bilgili and Ozturk 2015) for a panel of G7 nations from 1980 to 2009 and (Ozturk and Bilgili 2015) for a panel of 52 Sub-Saharan African countries from 1980 to 2009 both confirmed the growth hypothesis.

Neutrality hypothesis

Numerous contradictory studies imply that a uni/bidirectional link between renewable energy deployment and economic development does not exist, despite the vast amount of data that suggests otherwise. For instance, Menegaki (2011) performed Granger causality tests using data from the EU for the years 1997–2007 and discovered no indication of a connection between the use of renewable energy and European economic development. He has stated that the absence of a causal link between GDP and renewable energy consumption—defined as the absence of any causal association—may be attributable to the early phases of development and market penetration of renewable energy in Europe at the time. While using Toda-Yamamoto causality tests, Ertuğrul Yildirim et al. (2012) observed comparable results in their examination of the US economy from 1949–2006. Based on Granger's causality tests, Vaona (2012) established the presence of the neutrality hypothesis for Italy from 1861 to 2001 in different research. Therefore, one may conclude that there is no conclusive evidence of the direction or nature of the link between the consumption of renewable energy and economic development from the study of the literature in this section. In recent years, research has also provided evidence of mixed results. For instance, panel data modeling was utilized by Huang et al. (2008) for a sample of 82 nations from 1972 to 2002. According to the study, the neutrality and conservation hypotheses are valid for low-income and middle-income nations, respectively. Different research (Al-Mulali et al. 2013) examined 108 nations from 1980 to 2009. They found a bidirectional causal relationship in 80% of them, a neutral relationship in 19% of them, and a unidirectional relationship between growth and renewable energy in 2% of them. In recent research, Ntanos et al. (2018) used an autoregressive distributive lag model to examine the connection between the use of renewable energy and economic development for EU nations throughout the period 2007–2016. They supported the growth hypothesis for nations with a greater GDP per capita. In contrast, countries with a lower GDP per capita found support for the neutrality hypothesis. Kharlamova et al. (2016), (Rodríguez-Monroy et al. 2018), (Alper and Oguz 2016), and others all came to a similar result.

Objectives of the study

The economic development and growth of a country's economy depend heavily on its access to energy. It is extensively used in agriculture and related industries, including producing and distributing fertilizers, pesticides, and farm equipment. Homes require it for heating, lighting, and cooking.

Energy infrastructure will require commensurate expenditures as energy demand rises. Investments in the energy sector will increasingly need to focus on renewable energy to avoid becoming locked into unsustainable energy systems and realize the potential advantages over time. A significant increase in investment in renewable energy across all industries is required. The study's main objective is to trace the nexus between renewable energy and economic development. Renewable and non-renewable energy consumption and production are a heated topic in academia; however, most of the developed countries are focused more on renewable energy production and consumption. Developing countries energy consumption and production are not that advances yet. The policy makers need to be aware about the renewable energy consumption and production as well as its importance in economic development. This study selected EAGL's countries in particular because of the following reason. The sample of countries selected for the study is EGAL's countries. The name EAGLEs was coined in 2010 by BBVA Research to classify a set of developing economies that together are predicted to contribute more to global economic growth over the next decade than the G6 nations as a whole (G7 excluding the USA). Depending on how their economies are expected to develop in comparison to those of developed countries, the list of participating countries may shift over time. An annual adjustment is made to the EAGLEs' membership, and it is subject to change depending on how well developed economies are expected to fare economically in the future.

Literature review

The pursuit of stable growth while maintaining environmental quality is quickly becoming a hot subject among countries, academia, international organizations, and diverse stakeholders worldwide. Wang et al. (2023) studied the EKC hypothesis for 208 countries, the role of trade openness, energy natural resources rent, and human capital. The study used GMM to check to trace the relationship. After accounting for the impacts of trade liberalization, human capital, renewable energy consumption, and natural resource rents, the results demonstrate that the EKC hypothesis is supported. At the global level, the link between income level and carbon emissions exhibits an "inverted U-shaped" curve. For nations before the EKC turning point, increasing consumption of renewable energy has a greater effect on reducing emissions (effect size: 0.4334, compared to 0.1598), whereas for countries after the EKC turning point, increasing human capital has a greater effect on reducing emissions (effect size: 0.6311 compared to 0.3398). (iii) With a mitigating impact of 0.0615, the effect of trade openness on carbon emissions is only effective in nations with minimal decoupling following EKC turning points. Rents from natural resources, however, drive up carbon emissions in most nations. Similarly, M. A. Bashir et al. 2022a, b, c; Wang et al. (2022) investigate how urbanization has altered the relationship between economic expansion and ecological health. This research extends the classic EKC theory by including a social indicator for a panel of 134 nations for 1996–2015; this indicator corresponds to the three dimensions above (social, economic, and environmental). The findings indicate that urbanization reinforces the link between economic growth, carbon emissions, and ecological imprint. Despite the substantial body of research on the relationship between EC growth since the landmark study by Kraft and Kraft (1978), there has not been agreement among academics about the causality direction. The relationship between total NRE/RE growth also has been thoroughly studied by academics. For instance, (M. F. Bashir et al. 2022a, b, c, d) according to this study, the global energy industry is one of the most adversely impacted sectors since the mechanisms governing energy prices, demand for energy, and supply have all displayed significant ambiguity as a result of these exceptional economic and social shifts. To better understand how the industrial sector can manage energy consumption in the post-pandemic future, we present a quick summary of the demand, supply, and price structure of energy products and policy mechanisms. Afonso et al. (2017) found that NRE actively encourages development in Turkey, relying mostly on the autoregressive distributed lag (ARDL) approach and its modifications. Dogan (2016) found comparable results for a group of 28 countries. Al-Mulali et al. (2014) made a case for the growth-promoting impacts of NRE consumption. Through the dynamic panel, OLS (Ozturk and Bilgili 2015) verified these results for bioenergy in SSA. Li et al. (2021) studied the effects of economic, energy, structural, and social with per-capita carbon emissions. Considering the impacts of economic development and energy intensity, this research attempted to explore the influence of structural changes on per-capita carbon emissions across the four domains of energy, trade, society, and economy. Four income categories and 147 nations were examined from 1990 to 2015 using the ordinary least squares, completely modified ordinary least squares regression analysis, and Granger causality test. The findings indicated that the most important factors influencing carbon emissions at the global level were, respectively, economic growth and economic structure. According to academic research, growth benefits total energy consumption irrespective of the method utilized. An OLS analysis conducted for China and evaluating total RE, (Fang 2011) reported similar findings. On the contrary, ARDL-supported research by Razmi et al. (2020) reveal that despite some encouraging short-term effects, RE has less of a long-term effect on Iranian growth. Ozcan and Ozturk (2019) revealed comparable findings for RE in emerging nations by utilizing bootstrap panel causality. Numerous scholars emphasize that NRE Granger-cause development utilizes different causality analyses. Similar results for developing countries are also highlighted by Destek and Aslan (2017); Yilanci et al. (2021). Opposite to what is generally believed, Ozturk and Acaravci (2011) demonstrated a negligible effect of electricity on the economy in the MENA region. The evidence supporting conventional energy sources' convincing ability to promote economic growth may be found in a research survey on these energy sources' social and economic impacts (M. A. Bashir et al. 2022a, b, c; Shahbaz et al. 2021). The current study examines how economic complexity affects environmental quality in RCEP nations between 1990 and 2019 while accounting for urbanization, the use of renewable energy, financial development, and energy innovation. Our empirical findings support a considerable short- and long-term correlation between environmental quality, the economic complexity index, the use of renewable energy, financial development, urbanization, and energy innovation. The use of coal harms the process of emerging economies, whereas the usage of natural gas has mixed results in developing nations. From 1980 to 2015, the effect of NRE on development among major oil suppliers in Africa indicated an unbalanced relationship between the previous and carbon dioxide emissions in all but Algeria (Awodumi and Adewuyi 2020; Bashir 2022). Examine how trade affects the decoupling of carbon emissions and under what conditions trade might aid in the decoupling of emissions. Panel data from 124 nations were used in the empirical investigation, which covered the period from 2000 to 2018. The findings indicate that poor decoupling was the primary condition of the link between trade openness, economic growth, and carbon emissions. The latest findings highlighted how improvements in NRE usage in Nigeria slow economic growth and reduce CO2 emissions. A rise in NRE use in Gabon supports economic development and environmental welfare. In Egypt, the use of NRE kinds enables larger rates of growth. Hence, there are no significant implications for environmental quality. Better economic development results from changes in NRE utilization in Angola, while the effects on emissions vary according to the period and fuel used. Suppose they continue to exploit their plentiful resources. In that case, petroleum and natural gas policy-making in African oil-producing nations must consider encouraging RE technology to pursue growth. It is important to provide mechanisms for rewards and penalties to encourage conformity to environmental regulations. Based on a different kind of analysis, some other studies explained the connection between RE demand and economic growth in seven countries, including India, Mexico, Russia, China, Indonesia, and Turkey, from 1992 to 2012 and highlighted a long-term GDP relationship among GDP, RE utilization, and others. In other words, real economic growth in the above seven countries is facilitated by RE consumption. The growth hypothesis only applies to Peru in the RE situation, according to the bootstrap panel causality consequences of both RE and NRE on economic growth in 17 rising nations (Destek and Aslan 2017). With unidirectional causation extending from growth to EC, the conservation hypothesis is validated for Thailand and Colombia, whereas the feedback hypothesis is true for Greece and South Korea. The neutrality hypothesis is true for Turkey but not for the other emerging economies, where there is no correlation between NRE utilization and economic growth. As per the growth hypothesis, consumption of energy and growth are causally related in Brazil, China, Colombia, and the Philippines. In addition, Egypt, Portugal as well as Peru show unidirectional causality from economic growth to NRE; Turkey shows bidirectional causality with both NRE use and growth (the feedback hypothesis), and the rest emerging economies do not show any connection between the consumption of energy and economy growth (the neutrality hypothesis). Maji (2015) discovered a non-significant association between RE and economic growth in the near term and a negative correlation between the two over the long run. This supports earlier research, which highlighted how RE negatively impacted economic growth in Turkey, and Mexico (Pao et al. 2014). The relationship between RE and NRE growth is for these four developing countries (Turkey, South Korea, and Mexico). According to Venkatraja, the BRIC states' economies may have grown more quickly due to the reduction of RE in overall energy usage. In their study, Shakouri and Khoshnevis Yazdi (2017) looked at the relationship between a number of factors, including development, RE, and energy usage in South Africa from 1971 to 2015. According to the empirical results, RE supports economic growth, which in turn encourages the usage of renewable energy sources. Venkatraja (2020) offers reasons in favor of the growth hypothesis by using a panel data regression implemented in the BRIC countries of Brazil, Russia, India, and China over the period 1990–2015. The advancement of renewable energy is encouraged in order to accomplish energy growth, and additional developments in RE sectors are highlighted by the findings. In order to examine the long-term relationship between EC and economic development, (Zafar et al. 2018) differentiated energy, such as RE and consumption of NRE, and employed a second-generation panel to run the test on nations in the Asia–Pacific Economic Cooperation in the period of 1990–2015. The results demonstrated the beneficial effects of EC, including RE and NRE, upon the growth of the economy, an analysis of time series also suggested that RE had a driving part in the growth (Table 1).

Materials and methods

Granger has argued that ignoring other significant factors might lead to false causality. Numerous empirical studies using the Granger causality test have investigated the causal relationship in a two-variable setting. In addition, it is suggested by Lütkepohl (1982) that omitted variables in

Table 1 Prevailing research on the relationship between energy and economy

Author's	Time-Period	Countries	Variable	Methodology	Findings
Afonso et al. (2017)	1995–2013	Turkeyie	NRE	ARDL	Positive
Al-Mulali et al. (2014)	1980–2010	18 Latin American countries	Growth-promoting impacts of NRE consumption	OLS, Pedroni co-integration test	Positive
Razmi et al. (2020)	1990–2014	Iran	short-term effects, RE	ARDL	Positive
Awodumi and Adewuyi (2020)	1980–2015	Major oil suppliers in Africa	NRE	Co-integration analysis. Granger-cause	opposite
Destek and Aslan (2017)		17 rising nations	RE and NRE	bootstrap panel causality consequences	Applies to Peru in the RE situation
Ozcan and Ozturk (2019)	1990–2016	17 emerging countries	RE	bootstrap panel causality	Positive
Shakouri and Khoshnevis Yazdi (2017)	1971–2015	South Africa	RE	Granger causality	positive
Venkatraja, (2020)	1990–2015	BRICS	RE	Panel data regression	Positive
Zafar et al. (2018)	1990–2015	Asia–Pacific	EC, RE, NRE	Second-generation panel test	RE positive. NRE opposite
Dogan (2016)	1990–2012	EU	RE NRE	Dumitrescu-Hurlin non-causality	RE decrease CO2, while NRE cause increasing CO2
Fang (2011)	1978–2008	China	RE	Multivariate OLS	RE consumption Improve households income
Yilanci et al., (2021)					
Pao et al. (2014)	1990–2010	MIST	RE and non-clean energy	Panel co-integration	Positive
Ozturk and Bilgili (2015) v	1990–2009	G7	Biomass energy	Unit root, co-integration, DOLS	Biomass energy positive with economic growth
Wang et al. (2023)	1990–2018	208 countries	EKC	FMOLS and GMM	RE increase emission decreases
Li et al. (2021)	1990–2015	147 countries	Structural changes and emissions	LS and granger cause	Growth positive and structure opposite
Wang et al. (2022)	1996–2015	134 countries	Urbanization, EKC Economic growth	Threshold regression	Positive correlation between economy and growth by urbanization
Wang et al. (2022)	2000–2018	124 countries	Trade protectionism jeopardizes carbon neutrality-Decoupling and breakpoints roles of trade openness	Tapio decoupling, structural threshold	Weak decoupling. Among trade openness, economic growth and emission
Bashir et al. (2023)	1995–2019	Top 10 manufacturing countries	Energy transition AND environmental innovation	FMOLS, CCEMG, AMG	RE, Energy transition and environmental innovation negatively associated

Table 1 (continued)

Author's	Time-Period	Countries	Variable	Methodology	Findings
Bashir et al. (2022a, b, c)	1990–218	29 OECD	Institutions, environment and GHE	One step system GMM, two step system GMM	diversification negatively affects carbon emissions but promotes greenhouse gas emission
Bashir (2022)	2022		Pollution haven hypothesis	Keywords search	King Saud university and University and Wah Pakistan are productive. China is the geographical productive
Bashir et al. (2021)	1990–2019	RCEP	Environmental reforms, Paris climate agreement	AMG, PMG, FMOLS	Significant association between, environment, RE, financial development
Shahbaz et al. (2021)	1999–2020	Bibliometric analysis	tourism-environmental degradation		Ecotourism, economic growth, emission are hot spot

a bivariate system may result in non-causality. To bridge the gap in the prevailing literature, this study incorporated the Panel ARDL approach to finding the long- and short-run relationship between renewable energy and economic development for EAGLE's countries. Besides, this study also checked the granger causality among the variables selected for the study.

In economics, measuring long-term impacts or level linkages is crucial. Usually connected to a structural macroeconomic model's steady-state equation is "long-run relations." The same long-term relationships are frequently created under arbitrage situations inside and across markets. As a result, many long-run economic relationships, such as the Fisher inflation parity, uncovered interest parity, and specific model assumptions, do not constrain purchasing power parity. Other long-run relationships, such as those between macroeconomic aggregates such as consumption and income, output and investment, and technological advancement and real wages, are less based on arbitrage and thus more debatable. However, they still comprise a significant portion of what is generally accepted in empirical macroeconomic modeling. On the other hand, examining short-run impacts is model-specific and prone to identification issues.

Model of the study

$$EC = \beta_0 + \beta_1 RENEP_{jt-1} + \beta_2 RENECN_{jt} + \beta_3 CV_{jt} + \mu$$

where

EC dependent variable. Economic development. GDP per capita

RENEP renewable energy production/per capita

RENECN renewable energy consumption/per capita

CV control variables

Variables description

EC

The proxy used in this study to measure economic development is GDP per capita (Yilanci et al. 2021). "GDP per capita is the sum of the gross value added by all resident producers in the economy plus any product taxes (fewer subsidies) not included in the valuation of output, divided by the midyear population" (WDI, 2022). Renewable energy data was taken from "energy information administration." Control variables in the data are inflation, population, and gross fixed capital formation. The data for these variables are taken from the "World Bank" (World Development Indicators). The sample size of the study is from 1980 to 2019.

Results and discussion

Panel settings enable the reduction and removal of spillover impacts and worldwide shocks that cause misclassification and falseness in estimated models by testing for cross-section dependency across sampled nations. According to Baltagi and Hashem Pesaran (2007; Breitung and Pesaran (2008), geographical effects, common but neglected variables, or undiscovered factors can all contribute to cross-section dependency. Inconsistent estimators might result from ignoring cross-sectional dependence and using first-generational panel approaches that do not consider reliance. We use the LM test, CD test, and scaled LM test bias-corrected scaled LM test to determine if there is cross-sectional dependency among variables.

The literature argues that this variability between nations is caused by how developing economies have developed their energy and economic strategies (Ozcan and Ozturk 2019). The study's estimation begins by checking the pairwise correlation among the variables in the sample. The results of the pairwise correlations are reported in Table 2. It showed that no such problems could lead to bias estimation. Table 3 represents Hausman fixed effect estimations, one of the most common procedures for analyzing panel data. The results show that economic development, renewable energy production, and consumption positively affect EAGLE's countries. A unit increase in renewable energy production and consumption will increase economic development by 0.13 and 0.12%.

Usually, previous studies checked the relationship by using different econometric approaches to test economic growth and non-renewable energy productivity with renewable energy and so on. Therefore, to check the long-run and short-run relationship, particularly for EAGLE's countries, this study employed the Panel ARDL approach to trace the results. Table 4 reports the ARDL approach for the whole sample between renewable energy and economic development. The results of the estimations show that renewable energy consumption is a more substantial impact on economic development than renewable energy production in EAGLE's countries. The positive relationship between economic development and renewable energy

Table 2 Correlation metrix

Variables	GDPPC	REN	INF	POP	GFCF
GDPPC	1.000				
RENEPR	0.464	1.000			
INF	0.263	0.198	1.000		
POP	0.239	0.448	0.032	1.000	
GFCF	0.479	0.724	0.127	0.498	1.000

Table 3 Fixed effect model

Variables	GDPPC	GDPPC
RENEPR	0.139**	
	(0.0710)	
RENECN		0.122*
		(0.0726)
INF	0.0556	0.0253
	(0.0393)	(0.0396)
POP	−0.193*	0.0641
	(0.114)	(0.126)
GFCF	0.168*	0.129
	(0.0891)	(0.0906)
Constant	26.02***	22.14***
	(2.633)	(1.930)
Observations	461	422
R2	0.65	0.80

Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 4 Panel ARDL overall, renewable energy production and consumption with economics development

Variables	Model (1) GDPPC	Model (2) GDPPC
Long run		
RENEPR	0.0897**	
	(0.0535)	
RENECN		0.2538**
		(0.1338)
INF	0.0328***	0.2663***
	(0.0099)	(0.0340)
POP	0.5041**	0.3787***
	(0.1162)	(0.0129)
Short run		
COINTEQ01	−0.193***	−0.07289*
	(0.0551)	(0.0534)
D(RENEPR)	0.06401**	0.1675
	(0.0318)	(0.2590)
D(INF)	−0.01763	−0.0077
	(0.0127)	(0.0299)
D(POP)	−4.02374	0.3693
	(5.4066)	(2.2036)
C	0.26017*	
	(0.1028)	

Standard errors in parentheses***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

is consistent with the previous study (Bashir 2022; Chen et al. 2022).

Similarly, the relationship is also positive and significant in the short run. It shows that overall renewable energy has a positive relationship with economic development in the short and long run. The short-run relationship between renewable energy and economic development for each country is reported in Tables 5 and 6. Table 5 represents the short-run relationship between renewable energy production and economic development. The individual country analysis gave mixed results. The relationship between renewable energy consumption and economic development in Brazil, Indonesia, Turkey, and Russia is negative and significant. At the same time, the rest of the countries in the sample found a positive relationship with economic development in the short run. Table 6 represents the short-run relationship between renewable energy production and economic development. Again, the results were found to be mixed. For some countries, the relationship between renewable energy production and economic development has been positive and significant, while for the other countries, such as Brazil, Indonesia, Russia, and Turkey, it has been found to be negative. As mentioned above, the negative results between energy production and economic development in the sample can be explained by the many economic, social, and political factors that can affect the nexus. At the same time, the remaining countries of the sample which show a positive and significant association between renewable energy and economic development are Bangladesh, China, Egypt, India, Iran, Malaysia, Mexico, Nigeria, Philippines, and Vietnam. The results of this study support the previous studies by Omri et al. (2015); Singh et al. (2019). While the results of this study contradicts with some studies such as Maji (2015). The contradiction is found with the developing countries. The contradiction exists because of the following reason such as the economic situation and instability. Similarly, earlier study by Ocal and Aslan (2013) showed the RE negatively contribute the economy.

We may conclude that the current analysis adds to the body of knowledge, shows substantial variation across developing nations, and highlights the need for the link between renewable energy production and consumption in developing and developed countries. Table 7 represents a well-known method for estimating panels, the cross-sectional dependence (OECD) test. The (Breusch and Pagan 1980) LM test, (Hsiao and Pesaran 2004) scaled LM test, and (Pesaran et al. 2004) CD test are the most popular CD tests for panel data; all three reject the null hypothesis of zero dependencies for all study variables.

Table 8 shows the statistical hypothesis test; the Granger causality test was initially introduced in 1969 to determine if one-time series can be used to predict another reliably. The Granger causality test has an elementary theoretical foundation. Regressions often only reveal "mere" correlations, but C. Granger showed that causality in economics might be evaluated by gauging how well a time series can be predicted based on its past values.

Table 5 Panel ARDL, individual country renewable energy consumption with economic development

Countries	COINTEQ01	D(RENECN)	D(INF)	D(POP)	Countries	COINTEQ01	D(RENECN)	D(INF)	D(POP)
Bangladesh	−0.04091***	−0.36981***	−0.098***	−3.2723*	Nigeria	−0.1399***	3.6281	0.2216***	−8.4362
	(8.49E−05)	(0.00569)	(0.0056)	(0.7035)		(0.0030)	(5.9541)	(0.0061)	(12.9909)
Brazil	0.0194***	−0.1057**	−0.085***	0.5588	Pakistan	−0.1039***	0.7332	0.0606**	−7.6625
	(0.00012)	(0.0331)	(0.0000)	(0.3833)		(0.0038)	(3.1346)	(0.0101)	(19.2697)
China	0.04396***	0.33189***	−0.012***	16.55251*	Philippines	−0.0310***	−0.6665***	0.0154**	−1.4135
	(0.00012)	(0.0139)	(0.00011)	(6.5484)		(0.0026)	(0.0494)	(0.0003)	(5.6161)
Egypt	0.01067***	−0.02705**	0.0068***	1.1997**	Russia	−0.075***	−0.005	−0.002**	−1.479
	(0.0012)	(0.0036)	(3.9E−05)	(0.0353)		(0.000)	(0.065)	(0.000)	(42.190)
India	−0.0592**	0.1004**	−0.0036**	−8.2336	Turkiye	−0.7935***	0.0935	−0.3532**	2.3345
	(0.00031)	(0.02684)	(0.00012)	(6.47E+00)		(0.0145)	(0.0628)	(0.0079)	(13.2106)
Indonesia	−0.0247**	−0.1790**	−0.078***	−0.7327	Vietnam	0.002***	−0.045**	0.004***	2.900***
	(0.0009)	(0.0203)	(0.0001)	(9.8951)		(0.000)	(0.005)	(0.0000)	(0.534)
Iran	0.0070	0.0042	0.0472***	0.2519	Mexico	0.0487***	−0.1726*	−0.092***	−4.2100
	(0.0056)	(0.0029)	(0.0009)	(14.2711)		(0.0019)	(0.0768)	(0.0011)	(7.8456)
Malaysia	0.0426***	−0.1429**	0.0151***	−2.8191					
	(0.0012)	(0.0275)	(0.0011)	(6.7404)					

Standard errors in parentheses***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 6 Panel ARDL, individual country renewable energy production with economic development

	COINTEQ01	D(RENEPR)	D(INF)	D(POP)	C		COINTEQ01	D(RENEPR)	D(INF)	D(POP)	C
Bangladesh	0.0072***	0.0005**	−3.0283***	−0.0056**	0.4033**	Mexico	−0.0533***	−0.0677***	2.2916	−0.086**	−2.1589
	(0.0043)	(0.0009)	(0.0975)	(0.0001)	(0.0945)		(0.0012)	(0.00041)	(8.4044)	(0.0037)	(2.4469)
Brazil	−0.0062*	−0.0071**	9.422	0.8030	−0.3723	Nigeria	−0.01189**	0.0782***	89.0840	0.0575	−2.8445
	(0.0026)	(0.0017)	(114.7122)	(0.8673)	(3.9209)		(0.0007)	(0.0027)	(357.266)	(0.0527)	(2.3592)
China	0.0009***	0.0022***	0.7940**	−0.118**	0.1296	Philippines	−0.1774**	0.0578**	38.0437	0.7077**	−8.5640
	(0.0001)	(0.0001)	(9.0812)	(0.0066)	(0.1246)		(0.0090)	(0.0058)	(52.9499)	(0.0876)	(29.4547)
Egypt	−0.08031**	0.218215**	−18.978	−0.166	−2.8488	Russia	−0.0419***	−0.0097**	−6.3596	−0.0568	−1.7530*
	(0.0042)	(0.0123)	(37.1156)	(0.2802)	(8.5442)		(0.0002)	(0.0003)	(40.9639)	(0.0518)	(0.7459)
India	−0.09733**	0.01330	−12.64782	−1.437*	−4.3690	Turkiye	0.5285***	−0.1705**	12.2251	0.2272**	−21.0170
	(0.0044)	(0.0295)	(54.757)	(0.4833)	(13.9794)		(0.0094)	(0.0043)	(105.146)	(0.0112)	(74.6148)
Indonesia	−0.0760**	−0.0411**	−1.7706	0.0974**	−3.2719	Vietnam	0.0596**	0.0067**	2.9115	−0.057**	0.0280
	(0.0026)	(0.0010)	(26.1047)	(0.0105)	(6.1549)		(0.00023)	(0.0001)	(23.5843)	(0.0014)	(0.0443)
Iran	−0.0519***	0.0176***	2.5095	0.0217**	−2.1178						
	(0.01879)	(0.0004)	(2.2215)	(0.0010)	(3.1502)						
Malaysia	−0.0010	0.0108**	−4.2686	−0.087**	0.0712						
	(0.0010)	(0.0004)	(11.7662)	(0.0069)	(1.3579)						

Standard errors in parentheses***$p<0.01$, **$p<0.05$, *$p<0.1$

Table 7 Cross-sectional dependency test

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
GDPPC	1331.3920	84.6291	84.4368	−2.2703
	(0.0000)	(0.0000)	(0.0000)	(0.0232)
RENEPR	2239.0450	147.2631	147.0708	42.7387
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
RENECN	1581.6230	101.8967	101.6380	36.1221
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
INF	521.2996	28.7274	28.5351	17.6034
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
POP	3600.403	241.206	241.013	56.112
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

p-values in parenthesis

Table 8 Granger causality test

Null Hypothesis:	W-Stat	Zbar-Stat	Prob
RENPR does not homogeneously cause GDPPCC	9.7808	12.7170	0.0000
GDPCC does not homogeneously cause LRENPR	2.60253	3.55015	0.0004
INF does not homogeneously cause GDPPCC	3.1094	1.4966	0.1345
GDPPCC does not homogeneously cause INF	2.6984	0.8357	0.4033
POP does not homogeneously cause GDPPCC	11.9007	16.5756	0.0000
GDPPCC does not homogeneously cause POP	7.5635	9.2148	0.0000
INF does not homogeneously cause RENPR	1.6680	-0.8078	0.4192
RENPR does not homogeneously cause INF	3.6638	2.5047	0.0123
POP does not homogeneously cause RENPR	8.0227	9.9848	0.0000
RENPR does not homogeneously cause POP	4.5463	4.0898	0.0000
POP does not homogeneously cause INF	5.9260	6.2592	0.0000
INF does not homogeneously cause POP	4.2017	3.3974	0.0007

Conclusion

This result demonstrates that the neutrality hypothesis predominates and that energy consumption and economic development are not reliant on one another.

Although some nations show substantial unidirectional causation and offer proof for the conservation and growth of hypotheses, the setting of the bootstrap panel causality majority conclusion showed no causal relationship between energy use and economic production. In many developing countries, the hypotheses of growth and conservation of renewable are validated after structural changes have been taken into account. In most selected emerging nations, the neutrality hypothesis continues to dominate the link between energy use and economic development. Despite these results, our study has the potential to add to the body of knowledge by showing that most rising nations do not consistently show a mutually exclusive association between the use of any RE and growth.

Additionally, the creation of innovative methods and equipment for renewable energy significantly increases employment by opening up new work possibilities. Finally, it is crucial to examine the policy ramifications of COVID instances. Despite the availability of medicines, the COVID pandemic still poses a significant threat to global growth; thus, enhancing elements that influence GDP growth might be encouraged to avert an additional economic crisis. Even in a pandemic where consumption is no more a trustworthy source of growth, the lacking connection between the consumption of energy and economic progress would have challenging economic recovery consequences. Therefore, considering that the pandemic has decreased the consumption of fossil fuels, this study encourages the development of numerous ways to enhance the causal relationship connecting renewable energy and growth. This may be accomplished using tools like financial ones. The impacts of specific renewable and fossil fuel sources' potential processes on economic progress may be the subject of future studies on the relationship between energy & economic development. Renewable energies are becoming increasingly competitive as well as being a clean, infinite energy source. In comparison to fossil fuels, these alternatives emit no greenhouse gases (which contribute to global warming) or harmful emissions, making them more versatile and more widely applicable. In addition, its prices are declining and at a sustainable rate, while the average cost trend for fossil fuels is in the other direction, notwithstanding their current volatility.

Recommendation

As mentioned above, with the help of extent literature on energy consumption and production with economic development, this study provides some recommendation which will help policy makers and stockholders in the decision-making process of conversion of energy from non-renewable to renewable energy. Most of the developing or emerging countries spends much of their income on traditional energy production. The non-renewable energy is costly. While the other side, renewable energy is less costly and having long-term benefits, renewable energy production and consumption are environmental friendly. Similarly, the countries taken as a sample are the emerging and growth-leading economies. These countries need to focus on renewable energy consumption and production. The renewable energy consumption and production are essential for the economic development. This study directs future studies in the production and consumption of renewable energy at micro level as well as on company and firm level. The results have the following possible policy significance. First, the variation in the causal relationship between economic growth and renewable energy use in developing economies shows that national energy policies are necessary. Secondly, a growth hypothesis for energy sources is illustrated by the considerable unidirectional correlation between the use of renewable and economic production in and Brazil. Thus, it may be argued that these nations should switch to sources of renewable energy in place of non-renewable ones. Therefore, both nations might implement policies that increase the use of renewable sources in products without hurting the economy. Third, nations that demonstrate the growth hypothesis in the situation of renewable energy should create laws encouraging investments in clean energy, contributing to renewable energy operations, and granting tax exemptions to facilities that produce renewable energy (Apergis and Payne 2012; Bashir 2022). Policies to save fossil fuels and the environment could coexist and not obstruct business operations. Fifth, nations with no correlation between the use of renewable energy and economic productivity may create energy-efficient technology to accelerate economic activity based on renewable resources and promote sustainable economic development.

Limitation

Due to the length of time covered, the research will be able to consider significant events like energy crises and oil price hikes. This study analyzed a group of emerging economies. Yet the conclusions may be generalized to other developing emerging economies. To investigate the impact of this study, may also be carried out on an international sample utilizing panel data from other countries. Future studies might examine the relationship between energy transformation and economic development. Similarly, renewable energy sources and different economic factors, such as the balance of payment, human capital, high inflation, or at the micro level among firms and companies of the developing countries.

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Data availability The data used in this study are publically available on the World Bank data bank and for energy-related is available on "Energy Information Administration."

Declarations

Ethics approval Not applicable. This manuscript does not involve researching humans or animals.

Consent to participate All of the authors consented to participate in the drafting of this manuscript.

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