Environmental Science and Pollution Research (2020) 27:25327–25339
https://doi.org/10.1007/s11356-020-08909-8

RESEARCH ARTICLE

Investigating the nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: evidence from E7 countries

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Received: 24 March 2020 / Accepted: 16 April 2020 / Published online: 28 April 2020

Abstract

The transition of most economies especially heavily industrialized nations like China, Turkey, Russia, India, Indonesia, Brazil, and Mexico fondly known as E7 are fast emerging economies with its impact on economic growth and ecosystem. On the above highlight, the present study explores the dynamic interaction between hydroelectricity energy, renewable energy consumption, nonrenewable energy consumption on economic growth over annual time frequency data from 1990 to 2018. To this end, Kao co-integration technique is adopted in conjunction with panel ordinary least squares, dynamic ordinary least squares, and fully modified ordinary least square estimators over the identified blocs while the heterogeneous causality test of Dumitrescu and Hurlin is employed to detect the direction of causality among the variables. Empirical result shows long-run analysis reveals long-run equilibrium relationship between the examined variables. Furthermore, a one-way causality relationship is observed between economic growth and nonrenewable energy, economic growth and renewable energy, and economic growth and pollutant emission. The present study identifies a U-shaped pattern among nonrenewable energy consumption and economic growth in the long-run. These findings suggest that as economic growth increases, there is less strengthening of energy from the nonrenewable energy consumption hence, portentous deterioration in nonrenewable usage while authenticating the proficiency of nonrenewable energy consumption in the E7 countries. Further policy prescriptions are rendered in the concluding section.

Keywords Energy consumption · Energy consumption hypothesis · Kao co-integration · Panel regression test · Heterogeneous causality · E7 countries

Responsible editor: Nicholas Apergis

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Introduction

Fossil fuel consumption is considered an essential tool for economic growth, although there is a worry within the globe about the rising of pollutant emission (CO_2) and environmental degradation. The Kyoto agreement projects how committed countries are to lessen greenhouse gasses by 5% and 18% since 1990 to 2020 respectively through the "Doha modification to Kyoto procedure" (UN. 1998; UN. 2012). The primary purpose of the 2020 package of energy climate is to make Europe an extremely energy-efficient, little CO_2 emission production society, and supplementing the portion of EU energy intake created after renewable assets to 20% at the 2020 possibility (EC. 2009; EC. 2010). Owusu and Asumadu (2016) investigation shows that the ambition with the environmental issues currently is how to decouple economic growth from CO_2

emission. Governments from various countries are optimistic about lessening CO_2 emission without it affecting the growth of their economy with the view that development in the economy does not always affect CO_2 emission to increase. Thus, it is relevant for policymakers and all energy participants to recognize the energetic collaboration among the variables in the examination for them to involve in active and healthy energy and green strategy creation.

For many decades, the energy within the nonrenewable sector has been helping the rapid increase in the globe's economy. The alternative idea of replacing nonrenewable energy with renewable energy came in when the problems associated with nonrenewable energy started affecting global warming. Technology advancement and the idea of environmental sustainability are helping renewable energy to be more significantly the best alternative to nonrenewable energy consumption. On the other hand, many of the developing and emerging countries are left behind in the renewable energy sector compared with the developed economics, while simultaneously, the entire world has agree to participate in worldwide evolution to sanitary and low CO_2 emission. That is, the developing subject form experiential examination in economy which energy-managed advance works is an evaluation commencing nonrenewable usage of energy to renewable usage of energy resisting the growth of the economy in countries which are beginning to develop.

Apergis and Payne (2012) brought out a revolution that undeniably, the investigation of the comparative effects of renewable energy usage, nonrenewable energy usage, and hydro energy sources on the growth of the economy delivers appreciated understanding on the designing and implementation of workable energy and green strategies.

The central focus of this paper currently is to observe the effect of hydroelectricity power production, renewable energy usage, and nonrenewable energy usage on economic growth in the E7 countries. All seven countries, as they are known as emerging countries, are among the fastest-growing economies in the world, which for this reason, are the fastest-growing energy-dependent countries. Most of the countries in the E7 energy mix are highly controlled by trade in fossil fuel. Nevertheless, their energy consumption per capita is way below compared with the developed countries. A similar rise is expected in the future, utilized by a mission to enhanced excellence life and space for swift growth of the industrial sector in current enterprises. Again, the investigation of these studies has been conducted on some of the countries within the E7. However, to our best of knowledge, no studies have taken the entire E7 countries to investigate renewable energy, nonrenewable energy, and again add hydroelectricity to check its effect on economic growth. Finally, this study intends to add to the existing literature on renewable, nonrenewable, hydroelectricity power consumption, and economic growth relationship. The present study circumvent for other covariate not accounted in previous literature. This positions the current study on a distinct front for insightful policy construction. Studies of this sort are arguably timely and worthwhile to the related literature given the global awareness for the cleaner energy sources.

The rest of the paper is organized as follows. Section 2 looks into the literature and overview of energy sector dynamics in the E7 countries. Section 3 discusses the materials and methods for the study, while section 3.4 deals with the estimation of various tests and analyzing them. In section 4, we deal with the discussion of the result of the finding presented in section 3.4. Finally, section 5 deals with the conclusion part of the paper with adequate policy direction.

Review of related literature

The study of energy consumption has been well-documented by many examinations, which mostly focus on developed or advance countries in the last decades. Nevertheless, little studies on this examination have been done on the emerging or developing countries in which the E7 is part. It is this situation which the current studies seek to fill by identifying the gap and focusing on the E7 countries.

Four stable mechanisms on causality implications have been generated on energy collection (Adedoyin et al. 2020a, b; Asongu et al. 2016, 2017; Sakodie and Adom 2018; Bekun et al. 2019a, b; Emire and Bekun 2019; Sakodie et al. 2019; Inglesi-Lotz and Pouris 2016). The theory of energy-directed growth is the area of earliest involvement. The theory shows various literatures enhance that economic growth drives how energy usage can be maximize (Ghali and El-Sakka 2004; Damette and Sghir 2013). The following aspect or area looks into the theory of conservation (Baranzini et al. 2013; Jamil and Eatzaz 2010), which explains that higher energy usage is said to be the reason of economic events. Feedback causality is the next area the third theory looks into. In this way, causality is detected from equal sides successively (Tang and Tan 2013; Lee et al. 2008). Lastly, the final area is centered on the theory of neutrality (Soytas and Sari 2006; Halicioglu 2009), which explains that causality will not be found in any direction, thus, from growth of the economy and intake of energy.

Additionally, Apergis and Payne (2010a, b) explored the relationship regarding clean energy use and economic development for a panel of 20 OECD members over the span 1985 to 2005 within a multi-stakeholder context. Due to the comparatively short period of time series results, a panel co-integration and error correction process is used to infer the causal relationship. The heterogeneous panel co-integration study shows a long-term correlation among real GDP, clean energy consumption, actual gross fixed capital creation, and labor force with optimistic and statistically relevant coefficients. Granger-causality findings suggest bidirectional causality between green energy use and economic development within long- and short-term both. Also, Balcilar et al. (2010) and Mennyah and Wolde-Rufael (2010) examined the association among renewable energy, energy intake, and growth in the economy within the South Africa economy. Data from the division of Energy and Minerals (DEM 2016) in South Africa shows a satisfaction evidence that the energy is driven by their economic activities. Fifteen percent of the national economic growth of the country was provided by the energy sector, which the top contributor was coal to the energy combination. Additional data from the World Bank (2019) proves that energy intake from coal for the nationwide is around 70%, even though 93% of the production of electricity is of the result of power plant of coal fire. Winkler (2007) studies prove that the result of high level of CO2 emission is a result of high dependence on coal by the South Africa economy. Furthermore, Apergis and Payne (2012) explore the connection regarding clean and nonrenewable energy use and economic development for 80 countries within a multivariate context over the period 1990–2007. Outcome analyses indicate that there was no variation between elasticity figures with regard to clean and nonrenewable energy use. The findings of the panel error model demonstrate a bidirectional causality regarding clean as well as nonrenewable energy use and economic development in both the short- and the long-term. There is also a bidirectional short-term causality regarding clean as well as nonrenewable energy use that shows the computational complexity of the two power sources. Additionally, Sebri and Ben-Salha (2014) examined causality among the growth of the economy and usage of renewable energy intake for the countries of Brazil, Russia, India, and China, within the period of 1971 to 2010. Autoregressive distributed lag (ARDL) and vector error correction model (VECM) were the techniques used to examine the association among the growth of the economic, energy intake from renewable usage, trade liberalization, and CO_2 release. There was a long-run equilibrium association among the control variables which was the result of the estimation. Again, there was a double-way causality association among the growth of the economy and energy from the renewable usage showing the theory of feedback. The feedback theory shows how energy gain from the renewable usage helps in expanding the economy of these countries. Apergis and Payne (2014), on the other hand, explored the factors of clean energy use per capita for a group of seven Central American states since 1980 to 2010. Actually, they acknowledged that there was a long-term relationship between the outlined variables, congruent association regarding per capita green energy use, per capita real GDP, per capita carbon pollution, real coal prices, and real oil prices with the corresponding positive and statistically relevant coefficients. A systemic split in the co-integrating collaboration occurred in 2002, coinciding with the creation of the Power and Environment Alliance with Central America program to increase the use of clean power technologies. Acknowledging the transformation in policy in 2002, they estimated a nonlinear smooth transformation vector error correction model showing that, for the post-2002 context, the per capita effect in clean energy demand on real coal and oil rates has risen relative to the pre-2002 era, as well as a stronger vulnerability of real GDP per capita to per capita greenhouse gasses.

In Tunisian economy, Ben Jebli's and Ben Youssef's (2015) investigation indicated a U-shaped environmental Kuznets curve (EKC) test in the causality within the short-run proving one-way directional within international trade, economic growth, emission from carbon dioxide, and energies from renewable production and nonrenewable production within the frame of 1980 to 2009. International trade and energy from nonrenewable production has a progressive long-run effect on CO_2 emission, and energy from renewable production was weak and had negative effect on CO_2 emission. Moreover, Apergis and Ozturk (2015) investigated the environmental Kuznet curve (EKC) phenomenon for 14 Nations in Asia over 1990–2011. They concentrated about how income and regulations in these areas have an effect on the connection between income and pollution (ecosystem). The quantitative system includes CO_2 production, GDP per capita, population density, property, business share of GDP, and four metrics that assess the efficiency of institutions. With respect to the existence of an inverted U-shaped relationship regarding pollution and per capita revenue, figures have the predicted indications and are statistically important, giving scientific backing to the emergence of an environmental Kuznet's curve phenomenon. More recently, Danish et al. (2017) examined the environmental Kuznet's curve (EKC) hypothesis in a country-by-country review of the importance of clean energy and nonrenewable energy use in Pakistan. For the period 1970–2012, a collection of econometric approaches was used. The results offer good evidence for the involvement of the EKC in the context of Pakistan. Findings indicate that clean energy plays a leading role in the elimination of carbon dioxide emissions and nonrenewable energy use, however, as the primary driving force behind carbon dioxide emissions. This is also known that there was a bidirectional causality, not only among clean energy use and CO_2 emissions, as well as regarding non-renewable energy use and rise in CO_2 releases. Sensitivity analysis is conducted to show that the research paradigm is robust and that the test results are true and accurate for decision consequences. These results show that the Government wants to increase involvement in clean energy initiatives that may lead to warming efforts.

Nevertheless, Wang et al. (2018) discussed the association regarding clean energy use, economic progress, and the Human Development Index for the period 1990–2014 in Pakistan using the two-stage least square (2SLS) process. Analytical findings suggest that clean energy use does not change the human growth condition in Pakistan. Actually, the higher the nation's income, the lower the rates of human growth. In comparison, CO_2 emissions are beneficial in raising the human growth index. Nevertheless, access to trade prevents the human growth cycle in Pakistan. In comparison, the causality study supports the long-feedback theory regarding the ecological component as well as the human growth cycle. However, Danish et al. (2019) examined biomass energy utilization and ecological degradation in the BRICs nations by using the generalized device moment method (GMM) template for an evidence-based approximation between 1992 and 2013. The findings suggest that biomass energy usage is a renewable energy source which reduces environmental contamination. The analysis also showed evidence for the existence of an N-shaped association regarding income and contamination, and concluded that trade accessibility was the only variable leading to contamination in the BRICS nations. Such findings will encourage decision-makers to recognize biomass energy as a renewable energy option in an attempt to establish both power stability and ecological protection. More recently, Danish and Wang (2019) investigated the connection among biomass energy and real income as well as CO_2 pollution for China. Scientific proof is focused upon the use of dynamic autoregressive distributed lag (DARDL) simulations, data collected between 1982 and 2017. The findings indicate a negative association regarding China's power use of biomass and CO_2 pollution, indicating that energy usage of biomass tends to minimize contamination. Biomass electricity generation also lowers greenhouse pollution and may be the perfect option to fossil fuels. Appropriate regulatory consequences for biomass energy may be established, in particular, for the accomplishment of environmental sustainability objectives.

An overview of energy sector dynamics in the E7 countries

The emerging seven countries, which are popularly known as the E7, are made up of China, Turkey, Russia, India, Indonesia, Brazil, and Mexico. They are countries which are much into industrialization, and energy is the very key in their production. The LEA (2019) presents their energy dynamism as a fellow. Firstly, Mexico has a GDP billion 2010 USD as 1311, population in millions as 125. They produce world oil of 98.3 MB/D, share of global electricity generation at 2018 of 26%. They also have an improvement in average fuel consumption of light-duty vehicles as at 2017 of 0.7%. For other renewable generation, geothermal power generation of 92.7 TWH and solar power generation at 2018 of 570 THW. Again, China has a GDP billion 2010 USD as 10,161, population in millions as 1386. They have a share of global power mix of 38.5% at 2018 of coal and renewable energy share of global electricity generation of 26% at 2018. Moreover, India has a GDP billion 2010 USD as 2631, population in millions as 1339. The country has a share of global power of 38.5% in coal at 2018. They also have a share of global electricity generation in 2018 of 26%. Solar power generation at 2018 was 570 TWH and wind power capacity additions at 2018 of 51GW. Indonesia on the other hand has a GDP billion 2010 USD as 1090 and population in millions as 264. They produce a share of global power mix of coal of 38.5% at 2018. Again, they produce the world oil of 98.3 MB/D, and generation of natural gas was 3939BCM Brazil has a GDP billion 2010 USD as 2279 and population in millions as 209. At 2018, they were producing world oil of 98.3 MB/D and installed global hydropower capacity of 1307 GW. Lastly, Turkey has a GDP billion 2010 USD as 1237 and population in millions as 81. At 2018, they were sharing the global electricity generation of 26%, oil production of 98.3 MB/D, and natural gas production of 3937 BCD (www.lea.com).

Materials and methods

New allegations made in the 5th Assessment Document of the intergovernmental panel on environmental control (IPCC) draw out the significance of government entities to understand that the major component of greenhouse gas pollution is the output of heat and electricity from energy demand or utility infrastructure, relative to agricultural operations, transportation utilities, and the use of oil (IPCC 2016). This is focused on these revelations that the Emerging Seven (E7) has paid specific attention to all initiatives aimed at improving processes and performing structural mechanisms that would be smart enough to recognize, avoiding and managing inefficiencies in green governance. In the E7 nations, the implementation of the Kyoto agreement program, which estimated the determination of nations to eliminate greenhouse gas emissions by 5% and 18% from 1990 to 2020 respectively by the "Doha adjustment to the Kyoto protocol" (UN. 1998; UN. 2012), called for Member States to take the required action to ensure that the development agenda would be focused for sound environmental policies.

Furthermore, the world energy–related CO_2 pollution stalled by about 33 gigatons (Gt) in 2019, after 2 years of rise. This was primarily attributed to a rapid decrease in CO_2 pollution from the power sector in industrialized economies, owing to the growing position of renewable energy (primarily wind and solar PV), the transfer in fuel from coal to natural gas, and higher nuclear production. Global carbon pollution from coal consumption decreased by almost 200 million tons (Mt) or 1.3% from 2018, compensatory increases in oil and natural gas pollution. Developed economies witnessed their pollution fall by more than 370 Mt (or 3.2%), with the power sector accounting for 85% of the drops. Warm climate in many major nations has had a substantial impact on developments relative to 2018, lowering pollution by about 150 Mt. Slower global growth has already played a significant role in censoring the rise in pollution in key developing economies, including countries within the E7. Pollution projections for 2019 show that renewable energy transformations are ongoing, driven by the electricity sector. World pollution from the power industry has reduced by certain 170 Mt or 1.2%, with the greatest reduction happening in developing economies, where CO_2 concentrations have never been seen until the late 1980s (when electricity intake was one-third smaller) (IES, 2019).

Materials

To identify the long-run and causality association among economic growth (GDP), carbon dioxide emission (CO_2), total population (POP), openness of trade (TO), energy produced from hydroelectricity sources as electricity (HYE), energy from renewable intake (REC), and energy from nonrenewable intake (NREC) in E7 countries, data form the variables named above were extracted from the World Bank Displays (www.databank.worldbank.org).[1] Yearly data of frequency from the period of 1990 to 2018 was applied to investigate the relationship between the variables. The examination variables were converted to logarithmic form to help reduce the situation of heteroscedasticity. GDP was denoted by GDP per capita (constant 2010 US$), REC was denoted by renewable energy consumption (% of total final energy consumption), NREC was also denoted by fossil fuel energy consumption (% of total), POP was represented by population total, HYE was denoted by electricity production from hydroelectric sources (% of total), CO_2 was denoted by CO_2 emissions (kt), and TO was also denoted by trade (% of GDP). These studies expressed it functional relationship as (Soytas and Sari 2009; Bento and Moutinho 2016);

$$GDP = f\ (CO_2, POP, TO, NRE, RE, HYE) \tag{1}$$

$$\begin{aligned} LnGDP = \alpha + \beta 1LnHYEt + \beta 2LnRECt + \beta 3LnNRECt \\ + \beta 4LnCO2t + \beta 5LnTOt + \beta 6LnPOPt \\ + \varepsilon t \end{aligned} \tag{2}$$

where α is the constant term, $\beta's$ are the slope parameters which need to be estimated, ε shows the error tem, and t represent the time frame.

The long-run interaction among the variables was estimated with the help of Kao (1999) to identify the co-integration among the variables. Before the co-integration test, there was an examination of the stationarity properties. The current study therefore engaged the traditional ADF and PP unit root tests (see in Table 1). Once it was clear of that, there was order of integration among the series, we attempted to employ the Kao residual co-integration test (Kao 1999) to examine the presence of co-integration between the variables. The Kao examination has a significant theory of no co-integration and substitute of co-integration between the variables.

Stationary test

Subsequently, there is a need to verify if there is stationarity among the variables, such as real GDP, CO_2 emission, energy from hydroelectricity power, energy from renewable intake, energy from nonrenewable intake, openness of trade, and total population. The result indicated that there was no stationarity at all levels, but there was a present stationarity at the first difference among the variables when we employed two-unit root test. From the analysis, the order of one integration was shown.

Co-integration test

To identify the presence of stationarity within the variables, there was a need to test for the existence of co-integration in the long run. The researchers adopted the co-integration technique of the panel co-integration employed by Kao (1999) to investigate the existence of the long-run relation between real GDP and the other variables for the set of data within the E7 countries.

The result of Kao residual co-integration test (Kao 1999) presented above in Table 2 confirms the existence of co-integration among the variables. The empirical

[1] For brevity, more descriptions are presented in Appendix 1 and basic summary statistics into the data are in appendix 2.

Table 1 Unit root test results

UNIT ROOT TEST RESULTS TABLE (ADF)								
At Level								
		LNGDP	**$LNCO_2$**	**LNHYE**	**LNREC**	**LNNREC**	**LNTO**	**LNPOP**
$\pi\tau$	**t-Statistic**	0.9301	0.1291	0.0724	0.1959	0.0051	0.0000	0.5434**
	Prob.	**(0.7014)**	**(0.7467)**	**(0.2405)**	**(0.8234)**	**(0.8686)**	**(0.7958)**	**(0.0500)**
$\pi\vartheta$	**t-Statistic**	0.0401	0.5235	0.0006**	0.0025	0.0004	0.0736**	0.0029
	Prob.	**(0.1543)**	**(0.4670)**	**(0.0117)**	**(0.1265)**	**(0.1152)**	**(0.0247)**	**(0.9800)**
At First Difference								
		ΔLNGDP	**ΔLNCO2**	**ΔLNHYE**	**Δ LNREC**	**ΔLNNREC**	**ΔLNTO**	**ΔLNPOP**
$\pi\tau$	**t-Statistic**	0.1383***	0.0097***	0.0002***	0.0000***	0.0001***	0.0000***	0.3448
	Prob.	**(0.0001)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0019)**	**(0.9027)**
$\pi\vartheta$	**t-Statistic**	0.3127***	0.0217***	0.0014***	0.0000***	0.0005***	0.0000**	0.7289
	Prob.	**(0.0004)**	**(0.0003)**	**(0.0000)**	**(0.0001)**	**(0.0001)**	**(0.0112)**	**(0.1736)**
UNIT ROOT TEST TABLE (PP)								
At Level								
		LNGDP	$LNCO_2$	LNHYE	LNREC	LNNREC	LNTO	LNPOP
$\pi\tau$	**t-Statistic**	0.7838	0.1339	0.0010	0.2780	0.0000	0.0007	0.6402***
	Prob.	**(0.7980)**	**(0.7207)**	**(0.3195)**	**(0.8706)**	**(0.8982)**	**(0.9290)**	**(0.0000)**
$\pi\vartheta$	**t-Statistic**	0.1621	0.5186	0.0000**	0.0025	0.0000	0.0008	0.9736
	Prob.	**(0.1767)**	**(0.4640)**	**(0.0117)**	**(0.1265)**	**(0.1152)**	**(0.2469)**	**(0.6955)**
At First Difference								
		ΔLNGDP	**$\Delta LNCO_2$**	**ΔLNHYE**	**Δ LNREC**	**ΔLNNREC**	**ΔLNTO**	**ΔLNPOP**
$\pi\tau$	**t-Statistic**	0.1383***	0.0097***	0.0000***	0.0000***	0.0001***	0.0000***	0.4424
	Prob.	**(0.0000)**	**(0.0000)**	**(0.0001)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.6194)**
$\pi\vartheta$	**t-Statistic**	0.3742***	0.0215***	0.0000***	0.0000***	0.0000***	0.0000***	0.3864
	Prob.	**(0.0002)**	**(0.0002)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.6414)**

***, **, and * are 1%, 5%, and 10% significant levels respectively; thus, $\pi\tau$ is with constant, and $\pi\vartheta$ is with constant and trend

Table 2 Kao's (1999) residual co-integration test results

	T-statistic	Prob.
ADF	− 2.270490**	(0.0116)
Residual variance	0.001736	
HAC variance	0.003622	

Note: ***, **, and * are 1%, 5%, and 10% significant levels respectively

result designates that the insignificant theory of no co-integration is overruled at 5% significant level. The result supports Pedroni panel co-integration test which supports the evidence of long-run relation and affirms Bekun et.al (2019a).

Estimation test

Furthermore, by using the Kao residual co-integration test to determine the long-run relationship among real GDP, CO_2 emission, renewable energy consumption, nonrenewable energy consumption, hydroelectricity power usage, trade openness, and population from E7 countries, ordinary least squares (OLS), dynamic ordinary least squares (DOLS), and fully modified OLS (FMOLS) methods developed by Pedroni (2001, 2004) are employed to examine the long-run elasticities among the variables. The result of the panel OLS, DOLS, and FMOLS estimations is summarized in the Table 3 below.

For us to find the robustness of the variable, we added and dropped some of the variable in base model form. Based on the result from the four models, we used to examine the variables by applying OLS, DOLS, and FMOLS. It was shown that hydroelectricity power usage was positively significant statistically at 1% level when we applied the OLS panel estimation in the first model but was not significant when we tried to check the robustness of the variable with DOLS and FMOLS. Subsequently, after dropping some of the variables to access the robust factor of the variable, it was clear that all the three estimations were statistically significant at 1% level. OLS was positively significant, which implies that by increasing hydroelectricity power consumption by 1%, real GDP will increase by 103.27%, but for DOLS and FMOLS, their significant levels were negative; thus, by increasing real GDP by 1%, hydroelectricity will decrease by 68.33% and 61.10% respectively. Renewable energy has a negative significance in all three estimations in the first model. By dropping some of the variables to check the robustness level of the variable, it was still showing that OLS was not even significant; DOLS and FOLS were significant but in negative form. Which means, by increasing real GDP by 1%, renewable energy consumption will decrease by 11.61% in OLS, 102.71% in DOLS, and 126.88% in FMOLS respectively. Energy from the nonrenewable intake shows a positive significant level in OLS and negative significance at DOLS in model one but by dropping some variables to check the robustness level of the variable. It was clear that OLS, DOLS, and FMOLS are all positively significant at 1%. It implies that, by increasing real GDP by 1%, there will be an increase in OLS, DOLS, and FMOLS in 338.30%, 98.91%, and 498.17% respectively. CO_2 emission, trade openness, and population all have a significant relationship with real GDP.

Heterogeneous panel causality test

After establishing a long-run elasticity between the variables, it was very important to identify if causality was observed in the short run. For this reason, we applied the pairwise (Dumitrescu and Hurlin 2012) panel causality examination. The importance of this methodology is that it adopts all the coefficient variables to be stationary that is different across sections.

The analysis from Table 4 above establishes that there is a unidirectional causality among real GDP and nonrenewable energy consumption at 1% significant level, real GDP and renewable energy usage at 5% significant level, real GDP and CO_2 emission at 10% significant level, and real GDP and trade openness at 5% significant level. We could not establish any bidirectional or unidirectional causality between real GDP and hydroelectricity power usage, and population.

Empirical discussion of results

From the analysis, we found that the estimations are in support of our hypothesis. We identify that the results of these studies are in line of the research objectives. The estimations were in line that growth of the economy influences energy from renewable intake, energy from nonrenewable intake, pollutant emission, and hydroelectricity power consumption. Our comparison of the long-run limitations with the short-run heterogenous parameter of the estimation from the econometric model to inspect if EKC exists indicates the existence of EKC hypothesis. The findings indicate that real CO_2 emission has a positive significant coefficient in both DOLS and FMOLS and a negative significant coefficient in OLS in the long-run, and in the heterogonous panel causality which represents the short-run, it is also significant. Therefore, it reviews that in the investigation model, an invented U-shape association among real GDP and CO_2 emission exists. It reviews that within the E7

Table 3 Panel data analysis long-run elasticities

	MODEL 1			MODEL 2			MODEL 3		
	OLS	DOLS	FMOLS	OLS	DOLS	FMOLS	OLS	DOLS	FMOLS
$LNCO_2$	-0.4129***	0.9025***	0.7303***						
	(0.0000)	(0.0026)	(0.0000)						
LNHYE	0.8270***	-0.3647	0.7303	1.0327***	-0.6833***	-0.6310***			
	(0.0000)	(0.1769)	(0.1600)	(0.0000)	(0.0000)	(0.0000)			
LNREC	-0.4948***	-0.5684*	-0.5605***						
	(0.0000)	(0.0645)	(0.0001)						
LNNREC	1.8174***	-5.0833**	0.5618				3.3830***	0.9891***	4.9817***
	(0.0000)	(0.0208)	(0.3249)				(0.0000)	(0.0000)	(0.0000)
LNTO	0.4709***	-0.2353	-0.0455	1.7089***	-0.4820***	0.4355***	-0.5289***	-0.3572**	0.0250
	(0.0015)	(0.2181)	(0.5512)	(0.0000)	(0.0094)	(0.0053)	(0.0022)	(0.0274)	(0.8474)
LNPOP	0.1783**	-0.5395***	-0.4817***	-0.0514**	-0.0157	-0.007897	-0.2174***	-0.0448	-0.0595*
	(0.0215)	(0.0005)	(0.0000)	(0.0190)	(0.7245)	(0.8440)	(0.0000)	(0.3039)	(0.0653)
R-Squared	0.648264	0.998565	0.980672	0.366527	0.989181	0.890020	0.317804	0.990856	0.930889
	MODEL 4								
	OLS	DOLS	FMOLS						
$LNCO_2$									
LNHYE									
LNREC	-0.1161	-1.0271***	-1.2688***						
	(0.1991)	(0.0000)	(0.0000)						
LNNREC									
LNTO	1.5163***	-0.3477***	0.1211						
	(0.0000)	(0.0072)	(0.1965)						
LNPOP	0.1609***	-0.1111***	-0.1205***						
	(0.0000)	(0.0012)	(0.0000)						
R-Squared	-0.46248	0.995017	0.965071						

***, **, and * are 1%, 5%, and 10% significant levels respectively

Table 4 Heterogonous panel causality test

Null hypothesis:	Zbar stat.	Prob.
LNNREC ≠ > LNGDP	1.42520	(0.1541)
LNGDP ≠ > LNNREC	3.05443***	(0.0023)
LNPOP ≠ > LNGDP	7.35547***	(2.E-13)
LNGDP ≠ > LNPOP	6.72221***	(2.E-11)
LNREC ≠ > LNGDP	1.41281	(0.1577)
LNGDP ≠ > LNREC	2.20784**	(0.0273)
LNCO2 ≠ > LNGDP	3.95956**	(8.E-05)
LNGDP ≠ > $LNCO_2$	1.86375*	(0.0624)
LNHYE ≠ > LNGDP	0.55001	(0.5823)
LNGDP ≠ > LNHYE	5.30176***	(1.E-07)
LNTO ≠ > LNGDP	4.10771**	(4.E-05)
LNGDP ≠ > LNTO	2.23130**	(0.0257)

*Denote rejection of null hypothesis at 10% significant level

**Denote rejection of null hypothesis at 5% significant level

***Denote rejection of null hypothesis at 1% significant level

≠ >was denoted by does not homogeneously cause

countries, greenhouse gasses can be reduced by growth in real GDP of the country. The finding from the result affirms the exemptions conducted by Acaravci and Ozturk (2010); Cole (2004); Galeotti et al. (2006); Cho et al. (2013). According to the results, there is a progressive association among real GDP and CO_2 emission in the short run by applying the heterogonous panel causality test. It therefore indicates that real GDP leads to less CO_2 emission over time.

There is a significant level in both positive and negative forms for hydroelectricity power usage from the OLS, DOLS, and FMOLS which confirms a significant relationship between real GDP and hydroelectricity power usage. But there was no causality among them. Our result shows that there is EKC existence for both renewable (geothermal, solar, wind, and bioenergy) and nonrenewable (oil, gas, coal) sources that are all used in producing energy in the form of electricity within the E7 countries. In the long run, there is a significant relationship between real GDP alongside renewable and nonrenewable energy consumption. There is also a unidirectional causality relationship among real GDP and renewable energy consumption and real GDP and nonrenewable energy consumption and it affirms the study of Bento and Moutinho (2016) which states that both renewable and nonrenewable energies help in producing electricity in Italy. It also shows a significant relationship among growth of the economy and trade openness and a uni-causality among them. Although there is a significant association among growth of the economy and population but there is no causality among them.

Conclusion and policy direction

This study investigated the presence of long-run and causality relationship between energy consumption from renewable, nonrenewable and hydroelectricity sources and growth of the economy in the E7 countries. The examination indicated the presence of long- run equilibrium association among growth of the economy, energy from the renewable intake, energy from nonrenewable intake, hydroelectricity power usage and with the other control variables, such as trade openness and population. The nonrenewable energy contribution to real GDP is positively significant which means as economic growth increases nonrenewable energy consumption also increases. However, renewable and hydroelectricity power usage, as economic growth increase it decreases; nevertheless, elasticity from the growth of the economy with respect to energy from the renewable intake and hydroelectricity is insignificant. CO_2 emission was also significantly related to economic growth.

Empirical result from heterogeneous panel causality test shows a unidirectional homogeneous causality between growth from the economy and energy from nonrenewable intake, growth from the economy and energy from renewable intake, growth from the economy and CO_2 emission as well as growth from the economy and openness of trade. There was presence of negative association among nonrenewable energy and economic growth, and the unidirectional relation among them shows that the implementation of energy conventional strategy resolve not only boundary the economy of the E7 countries but likewise lessen request for energy from the nonrenewable in return. This shows that governments within the E7 countries should remain in support of the persistent nonrenewable energy-exploring guidelines.

From a policy stand point, the analysis was clear that countries within the E7 rely much on fossil fuel (nonrenewable) which is significant to GDP. From this, we conclude that there is much production of CO_2 emission. It is therefore imperative for the policymakers within these countries to invest much in the expansion of both the clean power production (renewable energy) and the hydroelectricity power, which produces less CO_2 emission in the long run. However, economic strategies including tax relief for the development of clean energy, discounts for the construction clean power infrastructure, requirements for the portfolio of clean power sources, and the creation of markets for clean energy certificates to expand the energy supply to the E7 nations are encouraged. In contrast to the value of clean energy for global development, the extension of clean energy would also decrease reliance on global energy supplies, competitive oil, and natural gas prices on global markets, and minimize long-term ecological loss connected with greenhouse gasses.

Appendix 1. Explanation of statistical data

Variable	Explanation	Sources
Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.	World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.
CO2 emissions (kt)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
Population, total	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates.	(1) United Nations Population Division. World Population Prospects: 2019 Revision. (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) United Nations Statistical Division. Population and Vital Statistics Report (various years), (5) U.S. Census Bureau: International Database, and (6) Secretariat of the Pacific Community: Statistics and Demography Programmer.
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	World Bank national accounts data, and OECD National Accounts data files.
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	World Bank national accounts data, and OECD National Accounts data files.
Electricity production from hydroelectric sources (% of total)	Sources of electricity refer to the inputs used to generate electricity. Hydropower refers to electricity produced by hydroelectric power plants.	IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/
Fossil fuel energy consumption (% of total)	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

All data extracted from the World Bank data index

Appendix 2. Corrections matrix

	LNGDP	LNCO2	LNHYE	LNNREC	LNPOP	LNREC	LNTO
LNGDP	1						
LNCO2	-0.2602	1					
LNHYE	0.35399	-0.2861	1				
LNNREC	0.3670	0.3248	-0.4144	1			
LNPOP	-0.5600	0.8127	-0.24350	-0.1277	1		
LNREC	-0.5601	-0.3207	0.2031	-0.8373	0.19033	1	
LNTO	0.1640	0.0627	-0.6049	0.6005	-0.1985	-0.4938	1

Descriptive analysis

	LNGDP	LNCO2	LNHYE	LNNREC	LNPOP	LNREC	LNTO
Mean	8.450213	13.48717	2.970007	4.315089	19.26308	2.972611	3.724862
Median	8.901547	13.11499	2.833081	4.396941	19.01847	3.199113	3.845045
Maximum	9.620394	16.21952	4.536178	4.536850	21.05453	4.229727	4.705713
Minimum	6.355242	4.229727	1.257442	3.936049	4.229727	1.171799	2.718776
Std. Dev.	0.908782	1.276402	0.722663	0.194644	1.499233	0.918073	0.392830
Observation	203	203	203	203	203	203	203

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