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Beyond the environmental Kuznets Curve in E7 economies: Accounting for the combined impacts of institutional quality and renewables

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A B S T R A C T

This study explores the applicability of conventional environmental Kuznets curve (EKC) with an extension for the case of emerging industrialized economies, comprised of China, India, Brazil, Mexico, Russia, Indonesia, and Turkey, for annual time frequency from 1995 to 2016. This study is distinct from that already documented in the extant literature by extending the traditional EKC phenomenon by accounting for the combined impact of institutional quality and renewables in E7 blocs. The countries under review are known to be emerging and still at their scale stage of their growth path. As such, the need to explore the theme is pertinent for stakeholders. Empirical framework is built on second-generational panel econometrics strategies that consist of Augmented Mean Group, Common Correlated Effects Mean Group estimator, Driscoll-Kraay and Dumitrescu and Hurlin Causality analysis, which is superior to first-generation methods. Our study validates the EKC phenomenon in E7, i.e., where emphasis is placed on economic expansion relative to the quality of the environment. The EKC phenomenon is validated by the deteriorating effect of fossil-fuel energy consumption in the bloc. However, renewables are seen as a panacea to reduce pollution emission as renewable energy exerts a negative and statistical relationship with CO_2 emission over the sampled period. Additional results show that weak institution also dampens the quality of the environment in E7. These outcomes are suggestive to policy makers to reinforce their commitment to the quality of the environment in terms of growth and energy transition from fossil fuel to clean energy sources. Further policy prescriptions are presented in the concluding section.

1. Introduction

In recent years, environmental pollution has become a global threat. The major contributor to this pollution is carbon dioxide emission which has seen a surge over the years from 3.039 metric tons per capita in 1960 to 4.555 metric tons per capita in 2016 (World Bank World Development Indicators, 2020). As much as energy consumption is a main contributing factor toward economic growth, yet it has been identified as a major contributor to CO_2 emissions due to the combustion of fossil fuels, such as natural gas, oil, and coal for energy and transportation (Phong, 2019; Raza et al., 2015). To combat the global pollution challenge, each country must opt for an alternative source of energy, such as renewable energy, to ensure there is little to no compromise in economic growth at the detriment of the environment.

Although the whole world is exposed to the consequences of environmental pollution, it is expected that countries with the highest contribution to the most important anthropogenic greenhouse GHG emissions (CO_2) should shoulder a larger share of the responsibilities required to reduce it (Intergovernmental Panel on Climate Change IPCC, 2007; Shahbaz et al., 2013). Countries such as China, the USA, the EU

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region, India, and Russia with 9528.2, 4921.1, 3150.9, 2309.1, and 1587.0 Mt CO_2/yr. in 2018 (International Energy Agency IEA, 2018) are the world highest emitters of pollutants; therefore, the global success at achieving a cleaner environment largely depends on them. The high level of emission in 2018 is not surprising as the global demand for energy soared by 2.1% in 2017 compared to 1.2% in 2016 with China and India accounting for 40% of this increase (IEA, 2018).

The increase in pollutant is not expected to decrease in the future, due to the world economic growth projections, it is expected to grow at an average rate of 2.6% between 2016 and 2050 and the growth is projected to be primarily driven by the emerging developing countries (E7): China, India, Brazil, Russia, Turkey, Mexico, and Indonesia, with average growth rates of 3.5% over the next 40 years (PWC, 2017). The methodological approach used for the E7 growth projection by 2050 follows a robust long-term model of economic growth by Solow (1956, 1957) which helps in forecasting growth by accounting for the developments relating to several factors, including capital accumulation and technical progress, education, and knowledge developments, and, of course, demographic factors. The applied growth model has also been empirically explored in some other growth studies (Barro and Lee, 2001; Denison, 2011; Hao and Wei, 2015; Wilson and Purushothaman, 2003).

The E7 countries as described by Hawksworth and Cookson (2006) are the developing countries with the fastest population growth to become economically as strong as G7. By 2018, these countries already represented 47% of the world population, 26% of the world GDP, 40% of the world's energy consumption, and 44% of the world's CO_2 emissions. Due to rapid population growth, GDP growth, energy use, and CO_2 emissions, these countries are highly prone to the danger of climate change and environmental pollution, thus, it is imperative to understand the relationship and the determinants of CO_2 emissions in these countries.

There are a growing number of energy economics studies and some have also focused on institutional quality and policies due to the critical roles that these factors play in environmental qualities (Ozturk, 2010; Sarkodie and Strezov, 2019). While exploring the nexus between institutional quality and economic performance in a cross-country study using alternative institutional indicators, Knack and Keefer (1995) concluded that institutional quality helps reduce the environmental cost of economic growth. Also, Panayoutou (1997) argued that when and how improvement in environmental quality depends on government policies, social institutions, and functioning markets. Similarly, Welsch (2004) reaffirms the importance of institutional quality and rule of law by arguing that, if the institutional quality is flawed, firms would easily ignore environmental externalities and control of CO_2 emissions procedure. A recent study by Sadik-Zada and Loewenstein (2020) also revealed that some factors that are often closely influenced by the level of institutional quality, such as political rights and civil liberties, could exert negative impacts on per capita carbon emissions.

Therefore, since rule of law or institutional quality plays a crucial role in tackling the environmental issues, this study aims to investigate the relationship between CO_2 emission, economic growth, an alternative source of energy (renewable energy), and institutional quality within E7 countries. Policy makers need to understand the impacts of renewable energy consumption patterns and institutional quality on CO_2 emission to be able to design effective policies that will promote sustainable economic growth, especially within E7 countries. This study is also distinct from extant literature by extending the conventional Environmental Kuznets Curve (EKC) framework by the addition of the combined effect of economic globalization, institutional quality, and renewables to the EKC argument. This is done for E7 economies, which have recoded less documentation in the related literature. Additionally, we present a battery of econometrics analysis of second-generational panel methods, which are reputed to be superior to first-generational techniques to offer sound empirical coefficients and results for onward policy direction.

The rest of this paper is organized thus: Section 2 presents the literature review while Section 3 presents the model and data description. The interpretation and discussion of the results are presented in Section 3. Finally, Section 4 presents the policy recommendations and conclusions.

2. Literature review

The impacts of economic activities on environmental pollution have been of great interest to researchers and there is a sizeable body of empirical literature. Studies have shown that an increase in first-stage economic activities leads to an increase in environmental degradation as established by the EKC hypothesis (Arrow et al., 1996; Dinda, 2004; Ozturk, 2010; Sarkodie and Strezov, 2019; Soytas et al., 2007). The EKC hypothesis has drawn wide attention in various empirical studies and dwells on the main idea of a reduction in environmental degradation as often reflected in the inverted U shape nexus between economic growth and environmental degradation at a higher level of income (Ansari et al., 2020; Destek and Sinha, 2020; Onifade, Erdoğan, Alagöz and Bekun, 2021b; Ridzuan, 2019; Suki et al., 2020).

However, despite the huge body of studies, there is no consensus regarding the validity of the EKC hypothesis in the literature. This calls for concern on the scale and composition effects within the EKC framework, thereby prompting researchers in recent studies to further explore the inverted U-shape income-environment nexus. In this regard, Sadik-Zada and Ferrari (2020) observed that there is a need to broaden the EKC discussion from a national framework to a global scale within the context of climate change, which is an international issue as far as GHG emissions level is concerned. Thus, in this context, beyond just the income component of the EKC, the interplay between many factors, including institutional quality, renewables compositions, globalization, and other major energy indicators, would go to a great extent in explaining the dynamics of the EKC hypothesis in various economies. We have provided a comprehensive detail of extant studies for more insights into the energy-income and environment nexus in the literature survey in Table 1.

3. Empirical approach

3.1. Data description

This paper adopted a combination of various approaches to empirically analyze data on a group of seven emerging economies (the E7) to include China, India, Brazil, Mexico, Russia, Indonesia, and Turkey. The data are sourced from the World Bank development indicators from 1995 to 2016. These countries share some common economic traits with their fast-growing emerging status which has translated to substantial implications on energy-related developments alongside economic expansion in recent times. To assess the impacts of energy consumption and the current level of institutional quality in line with the level of economic globalization that is being witnessed among the E7 countries on their environmental quality, we provide a model specification for the empirical study in logarithm form in equation (1);

$$LnCO_{2it} = \alpha_0 + \alpha_1 Ln\mathrm{Y}_{it} + \alpha_2 LnEG_{it} + \alpha_3 LnY^2{}_{it} + \alpha_4 Ln\mathrm{NR}_{it} + \alpha_5 Ln\mathrm{R}_{it} + \alpha_6 Ln\mathrm{I}_{it} + \varepsilon_{it} \quad (1)$$

Data spanning from 1995 through 2016 were gathered from the World Bank (WDI, 2020), and the KOF globalization Index of Gygli et al. (2019). This study adopted the KOF Globalization Index of Gygli et al. (2019) as obtained from the KOF Swiss Economic Institute to capture economic globalization. The KOF globalization index is gaining more popularity in empirical literature due to its broad scope of capturing globalization compared to other narrow well-known approaches like the trade openness proxy that mainly capitalizes on trade dynamics in contextualizing the globalization measurement (Le and Ozturk, 2020; Shahbaz et al., 2018; Wang et al., 2018). Dreher (2006) developed the initial index, which was revised in Dreher et al. (2008). Gygli et al.'s

Table 1
A survey of the literature.

Authors	Year	Variables	Region	Period	Methodology	Findings
Bhattaria and Hammig	2001	DF, GDP,	66 Latin America, Africa, Asia			- Improvement in institutional structure and macroeconomic policy significantly reduces tropical deforestation
Dutt	2008	CO_2, GDP, IQ, ED,	Cross-country	1984–2002		- Countries with better institutional quality and greater investment in education have lower emissions
Tamazian and Rao	2010	CO_2, GDP, INF, FDI, PRLIB, FTRLIB, TO, IQ, EC, EI	24 transition economies	1993–2004	Random effect and GMM	- EKC hypothesis holds - FDI, IQ, and Financial development have a negative impact on carbon dioxide emission - Economic growth, TO, EC all have a deteriorating effect on the environment - Positive interaction effect between IQ and financial liberalization variables on environmental degradation
Menyah and Rufael	2010	CO_2, GDP, RE, NE	US	1960–2007	Toda and Yamamoto Granger Causality	- Unidirectional causality from nuclear energy consumption to CO_2 emissions but no causality from renewable energy consumption to CO_2 emissions.
Frondel et al.	2010	CO_2, RE, PV, feed-in tariff expenditure	Germany		Cost-benefit analysis	The adopted feed-in tariff scheme has failed to harness the market incentives needed to ensure a viable and cost-effective renewable energy Government spending on renewable energy has shown little long-term promise of stimulating the economy, protecting the environment, or increasing energy security
Aspergis et al.	2010	CO_2, GDP, R, N	19 developed and developing Countries	1984–2007	Panel error correction model	- In the long run there exists a negative relationship between nuclear energy consumption and emissions, but a positive relationship between renewable and emissions - In the short run, nuclear energy consumption plays an important role in reducing CO_2 emissions, whereas renewable energy consumption does not contribute to the reductions in emissions.
Goel et al.	2013	CO_2,GDP,CORR, TO,EDU, P,SE, D, GC,PC	144 Nations	2004–2007	2SLS	- Increase in shadow economy lowers the reported CO2 emissions, likewise greater corruption also misreports or underreports carbon dioxide emissions - Production characteristics captured by agriculture value-added, industrial production, the efficiency of energy consumption, and time dummies. Value added to agriculture and energy efficiency both lowers CO2 emissions, while industrial production and trade openness are linked with higher CO2 emission - MENA region in all instances shows higher emissions compared to other countries Education, population growth, and population density were statistically insignificant
Osabuohien et al.	2014	CO_2,GDP,IQ,TO	50 African countries	1995–2010	Panel Cointegration and Vector Autoregressive techniques	- EKC hypothesis holds - Jointly institutional quality, trade openness, and economic development can explain environmental pollution in the long run for the studied African countries
Lau et al.	2014	CO_2,GDP, IQ,X	Malaysia	1984–2008	Bound test	- Long run relationship exists between carbon dioxide emission, institutional quality, export and economic growth - Good institutional quality helps mitigate CO2 emission - Institutional quality does not only affect economic growth directly, but also indirectly through CO2 emissions
Ibrahim and Law	2016	CO_2,GDP,TO,URB, IIAG,M2,CREDIT	40 SSA countries	2000–2010	System GMM	- Economic development brings about environmental degradation - Trade, financial policies and institutional quality are beneficial to the environment - Urbanization is a threat to the environment
Sardokie and Adams	2018	CO_2,GDP, URB,IQ, RE, FE,EC, NUC	South Africa	1971–2017	ARDL	- EKC hypothesis Validated - Urbanization presents a weak and insignificant role in environmental pollution - There exists a long run relationship running from renewable energy, fossil fuel, nuclear energy, economic development and political institutional quality to environmental pollution
Wang et al.	2018		BRICS	1996–2015	Partial Least Square	

(*continued on next page*)

Table 1 (*continued*)

Authors	Year	Variables	Region	Period	Methodology	Findings
		CO_2,GDP,P,CI, URB, TO, CORR				- Corruption, population growth, GDP growth and urbanization are positively correlated with CO2 emissions - Trade openness is negatively correlated with CO2 emissions - Interaction effects between GDP growth and corruption, urbanization and corruption, revealed a positive effect of economic growth on reduced carbon emission. Also, the interaction effect of trade and corruption revealed that control of corruption weakens the negative impact of trade openness on carbon dioxide emission
Zakaria and Bibi	2019	CO_2, GDP, EC, FD, FDI, TO, IQ	South Asia (Bangladesh, India, Nepal Pakistan, and Sri Lanka)	1984–2015	2SLS, GLS	- EKC hypothesis holds - EC and FD, deteriorate the environment - FDI and IQ improve the environment
Salman et al.	2019	CO_2, GDP, TO, EC, IQ	South Korea, Thailand and Indonesia	1990–2016	FMOL, DOL, VECM granger Causality	- There exists a positive significant interaction variable between carbon dioxide emission and institutional quality, signifying efficient and impartial domestic institutions are important for economic growth and decrease in CO_2 emissions - Institutional quality, trade openness, and energy use stimulate economic growth - One-way causality from institutional quality to economic growth, carbon emission, and energy consumption - One-way causality from trade openness to carbon emission, from energy use to trade openness, and from energy use to carbon emission
Arshian et al.	2019	CO_2, GDP, RE, NRE, FD	74 Nations	1990–2015	FMOL, CIPS unit root	- EKC hypothesis holds - All variables are integrated in the long run - Non-renewable energy consumption has a positive impact on environmental degradation, whereas renewable energy has a negative impact on environmental degradation; it helps reduce environmental hazards. - Financial development has a negative and significant impact on environmental degradation
Le and Ozturk	2020	CO_2,GDP,EC,FD,IQ, FDI,G	47 Emerging markets and developing economies (EMDE)	1990–2014	Panel cointegration, Panel causality	- EKC hypothesis holds - Globalization, financial development, government expenditure, and institutional quality increase pollution for EMDEs
Sadik-Zada and Gatto	2020	CO_2,GDP,FE,OR, PRI,MVA	38 oil-producing countries	1960–2018	Multivariate panel co-integration techniques and two-stage fixed effects estimations	- EKC hypothesis rejected - A weak and monotonically increasing relationship was established

Note: EC energy consumption; FDI foreign direct investment; TO trade openness; FD financial development; IQ institutional quality/development; INF inflation; URB rate of urbanization; P population; EI energy imports; PRLIB price liberalization; FTRLIB forex and trade liberalization; CORR corruption index; G globalization; ED Education; SE Shadow economy; IIAG Ibrahim Index of African Governance; M2 Money supply; RE Renewable energy; FE fossil fuel energy; NUC Nuclear electricity net generation; NE nuclear energy; X export; N nuclear electricity net consumption; R total renewable electricity net consumption; NRE non-renewable energy; OR oil rent; PRI Political Rights Index; MVA Manufacturing Value Added.

(2019) revision of the index differs among de facto and de jure indicators of globalization's various dimensions. Additionally, they disentangle trade and financial globalization from the economic component of globalization and employ time-varying variable weighting. The latest index is based on 43 variables rather than the previous version's 23. Following Dreher (2006), they examined the impact of globalization on economic activity using the new index. The full description of variables in Eq. (1) is presented with the calculated summary statistics in Table A1.

3.2. Data analysis

Varying degrees of relationship are expected among the variables in Equation (1). Thus, in Table A2, we provide a simple correlation matrix to have a glimpse of what such relationships could resemble. As can be seen from Table A2, the relationship between the variables as depicted by the correlation matrix is reasonably low except for the case of energy consumption indicators (NR and R), and that of economic globalization (EG) and institutional quality (I). As expected, inter alia, a variable like economic globalization could actively be linked to some levels of interdependency among the countries of the panel study considering the current realities of both economic and financial interdependency among many emerging economies around the globe. As such, there may arise some level of concerns about possible cross-sectional dependency (CD) across individual units of the panel model and it is highly imperative to carry out a test in this direction (Chudik et al., 2016; De Hoyos and Sarafidis, 2006; Dogan and Aslan, 2017; Ozcan and Ozturk, 2019).

Table 2
Cross-sectional dependency (CD) test results.

Model	Pesaran (2007) CD Test	Pesaran (2015) LM Test	Breusch and Pagan (1980) LM Test
$LnCO_2 = f(LnY, LnY^2, LnI, LnEG, LnR, LnNR)$	−1.048***	−2.119**	557.77***
p-value	(0.0047)	(0.034)	(0.0000)

Note: ***, ** and * are 1%, 5% and 10% significance level, respectively.

Hence, for confirmation purposes, we reported cross-sectional dependency test results in Table 2 following the application of Breusch and Pagan (1980) LM Test, Pesaran (2007) CD Test, and Pesaran (2015) LM Test.

From Table A2, all the three tests affirm the presence of cross-sectional dependency following the statistical significance of the test statistics for the rejection of the null hypothesis of no cross-sectional dependence, thus, indicating the necessity to exercise some level of caution in selecting appropriate methodologies for both the intending unit-root test and cointegration techniques (Bilgili et al., 2017; Chudik et al., 2016). Following these results, conventional panel unit root tests as seen in some extant studies could pave way for misleading conclusions on the unit root status of the variables and the true nature of cointegrating relationships for the panel study (Adedoyin et al., 2020; Onifade, Alola, Erdoğan and Acet, 2021a; Sulaiman et al., 2020). Thence, to circumvent the associated methodological flaws in using conventional panel unit root test in the presence of cross-sectional dependence, we applied Panel IPS and CIPS test of Pesaran (2007) for the unit root analysis. The results of the unit root test from Table 3 show that the understudied variables are integrated of the first order I (1).

Having established the order of integration, we applied Westerlund (2007) cointegration technique that is founded on error correction mechanism (ECM) with the assumption that variables exist in their first order of integration to establish a cointegration relationship for the panel study. The error rectification method (ECM) of the estimation follows the expression in Eq. (2):

$$\Delta Y_{it} = \pi_i d_i + \theta_i\left(Y_{it-1} + \gamma_i^* X_{it-1}\right) + \sum_{j=1}^{m}\theta_{ij}\Delta Y_{it-j} + \sum_{j=0}^{m}\delta_{ij}\Delta X_{it-j} + \varepsilon_{it} \tag{2}$$

From Eq. (2), $\pi_i^* = (\pi_{1i}, \pi_{2i})^*$, representing the vector of parameters, while $d_t = (1-t)^*$, and θ_i are deterministic mechanisms, as well as the error correction parameter correspondingly. To identify cointegration existence, Westerlund (2007) approach produces four major statistics based on the least squares estimation and corresponding significance of the adjustment term θ_i of the ECM model in Eq. (2) and these statistics can be categorized under two major subdivisions, namely the group statistics and the panel statistics. The group mean statistics Gτ and Gα follow the derivations from the expressions in Eq. (3) and Eq. (4);

$$G\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha} i}{SE(\hat{\alpha} i)} \tag{3}$$

$$G\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha} i}{\hat{\alpha} i(1)} \tag{4}$$

where, $\hat{\alpha} i$ is denoted by $SE(\hat{\ }\alpha i)$ as the standard error. The semi-parametric kernel technique of $\alpha i(1)$ is $\hat{\alpha} i(1)$.

$$P\tau = \frac{\hat{\alpha} i}{SE(\alpha i)} \tag{5}$$

$$P\alpha = T\hat{\alpha} \tag{6}$$

The two remaining panel mean estimations prove that the entire panel is co-integrated, as shown in Eq. (5) and Eq. (6), where variables remained as earlier defined. The application of this test has been substantially reported in the literature as they are designed to accommodate cross-sectional dependency in a panel study (Alola et al., 2019; Baloch et al., 2020; Chudik et al., 2016; Gyamfi, Sarpong and Bein, 2020d; Le and Ozturk, 2020; Nathaniel et al., 2020).

The Westerlund (2007) cointegration test outputs in Table 4 provide enough evidence of cointegration among the variables while taking into cognizance the concerns about cross-sectional dependence as the probability values for the rejection of a null of an absence of a cointegration relationship is significant at 5% levels for the group statistics and relatively higher significance level for the panel statistics, respectively.

3.3. Panel estimations

Following the circumstances surrounding the results in Section 4.2, the panel estimators for the study should consequently take into cognizance the concerns on the cross-sectional dependence. Hence, we applied three robust techniques that are designed to accommodate the latter concern for the study. The Augmented Mean Group (AMG) heterogeneous panel estimator of Eberhardt and Bond (2009) and Eberhardt and Teal (2010), and the advanced Common Correlated Effect Mean Group (CCEMG) panel estimator of Kapetanios et al. (2011) as initially developed by Pesaran (2006) were utilized in the study following the expression in Eq. (7) and Eq. (8), respectively:

$$\Delta Y_{it} = \alpha_i + \beta_i\Delta X_{it} + \sum_{t=1}^{T}\pi_t D_t + \phi_i UCF_t + \mu_{it} \tag{7}$$

$$Y_{it} = \alpha_i + \beta_i X_{it} + \gamma_i Y^*_{it} + \delta_i X^*_{it} + \theta_i UCF_t + \mu_{it} \tag{8}$$

From the CCEMG expression in Eq. (8), the Y* and X* represent the mean values of the variables Y_{it} and X_{it} alongside the unobserved common effects while D is a time-variant dummy variable in Eq. (7). The OLS estimation of the differenced Eq. (7) is utilized to generate the AMG estimator as given in Eq. (9) where ϕ_i denotes the estimated slope parameters of the X_{it} variable in Eq. (7).

Table 4
Westerlund (2007) Cointegration test.

Statistics	Value	p-value
Gτ	−2.054**	(0.047)
Gα	−1.870***	(0.000)
Pτ	−2.670*	(0.071)
Pα	−0.881*	(0.091)

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

Table 3
Panel IPS and CIPS unit root test.

VARIABLES	CIPS				IPS			
	I(0)		I(1)		I(0)		I(1)	
	C	C&T	C	C&T	C	C&T	C	C&T
$LnCO_2$	−3.183	−2.682	−4.283***	−4.170***	−1.085	−2.214	−4.306***	−4.225***
LnY	−0.806	−1.071	−2.582***	−3.008***	1.783	−1.239	−2.661***	−3.348***
LnY^2	−0.816*	−0.068	−3.482***	−2.571**	1.323	0.159	−3.896***	−3.193***
LnI	−1.373	−1.380	−2.892***	−2.962**	−1.238	−2.261	−3.302***	−3.305***
LnEG	−2.940	−3.601	−4.346***	−4.286***	−1.578	−1.824	−4.262***	−4.555***
LnR	−1.733	−2.197	−4.394***	−4.994***	−1.336	−2.620	−5.346***	−5.293***
LnNR	−1.623	−1.601	−4.004***	−4.008***	−1.087	−1.372	−4.329***	−4.959***

Note: ***, ** and * are 1%, 5% and 10% significance level, respectively.

$$\text{AMG} = \frac{1}{N}\sum_{i=1}^{N}\phi_i \tag{9}$$

We also reported the linear regression estimates with Driscoll–Kraay (DK) standard errors while conducting a robustness check for multicollinearity through the variance inflation factor (VIF) as reported in the Appendix section. A combination of these approaches has been noted to be very efficient in producing robust estimates, especially when cross-sectional dependence issues have to be accommodated in a panel analysis (Hoechle, 2007; Le and Ozturk, 2020; Zhang and Lin, 2012). Even though our econometric model is straightforward, it is also very general. For example, in contrast to traditional cross-sectional and/or homogeneous panel techniques, which require the identification of quantifiable factors that can operate as substitutes for unobserved variables, our non-stationarity panel method incorporates a broad class of factors, such as institutions that show excellent path dependence and persist over time (de. V. Cavalcanti, Mohaddes and Raissi, 2011). Additionally, the unobserved common components of ε_{it} incorporate a variety of different factors that affect real income, but are difficult to quantify accurately. A further benefit of our nonstationary panel method is that the long-run relationships between the variables are directly estimated. This is in contrast to the more conventional stationary dynamic and static panel methods, which can unintentionally reveal high-frequency connections. Additionally, the approximations are super-consistent in the presence of cointegration and are resilient to the omission of factors not included in the equilibrium connection (Niklas and Sadik-Zada, 2019).

However, these techniques were utilized to evaluate the impact of economic globalization, institutional quality, renewable energy, and fossil fuel on CO_2 emission, where more emphasis was placed on whether income and income square could present the EKC hypothesis within the E7 economies.

Table 5 presents the coefficients from the estimators.

From Table 5, the adopted estimators, namely the AMG, the CCEMG, and the Driscoll-Kraay approach, produced relatively close results on the average, with little difference only observed in terms of the magnitudes of estimated coefficients and their corresponding level of statistical significance. Both economic globalization and renewable energy consumption were significant for achieving positive results in the quest for a cleaner environment among the E7 economies as these two variables have a significant negative impact on the level of carbon emission in these economies. The current findings from this study complement the results from contemporary studies on the possible ameliorating impact of globalization on carbon emission among countries (Gyamfi, Bein and Bekun, ; Saud et al., 2020; Zaidi et al., 2019). Increasing renewable energy consumption is a well-known propelling force for a quality environment and it is worth noting that economic globalization is expected to be an influential driver of this force among the understudied E7 economies. In addition, in line with a priori expectation, the empirical results also provide evidence that non-renewable energy consumption level on the other hand has a positive and significant impact on CO_2 emission for the panel of the E7 economies and it is in line with the studies of Gyamfi, Adedoyin, Bein, and Bek (2021b) and Le and Ozturk (2020).

Table 5
AMG, CCEMG and Driscoll-Kraay result.

Dependent Var LnCO_2	AMG	CCEMG	Driscoll-Kraay
LnY	0.4727***	0.302*	0.341***
p-value	(0.000)	(0.077)	(0.000)
LnY^2	−7.750*	−1.270*	−7.510**
p-value	(0.062)	(0.074)	(0.047)
LnI	0.0667**	0.0108**	0.169**
p-value	(0.026)	(0.032)	(0.047)
LnEG	−0.066***	−0.135*	−0.001*
p-value	(0.001)	(0.052)	(0.077)
LnR	−0.0115**	−0.037*	−0.003**
p-value	(0.031)	(0.070)	(0.015)
LnNR	2.006**	1.268*	2.263***
p-value	(0.002)	(0.077)	(0.000)
Wald test	30.06***	18.11*	90.03***
p-value	(0.0000)	(0.0504)	(0.0000)
No. Regressors	6	6	6
No. Observations	154	154	154
No. Group	7	7	7
R^2			0.6498

Note: ***, ** and * are 1%, 5% and 10% significance level, respectively.

Furthermore, on the income aspects of the study, the results reflect a cushioning role of income growth on carbon emission among the E7 economies. As the impacts of income level (Y) and growth in income level (Y^2) are positive and negative, respectively, the empirical findings support the inverted U-shape assumption that substantiates the validity of the environmental Kuznets Curve (EKC) for the E7 economies. This indicates that pollution rises during the early stages of economic growth, but declines during the later stages of economic growth. An economic expansion that translates to higher income levels among these nations is expected to assist in pushing these economies toward environmental sustainability and the findings affirm the study of Gyamfi et al. (2021b).

However, the results show that the level of institutional quality plays a significant role in exacerbating carbon emission among the E7 economies as the institutional quality proxy (I) came out with a positive significant coefficient. This finding affirms the study of Ibrahim and Law (2016) and Godil et al. (2020) In a nutshell, this result calls for more attention on the crucial roles of transparency, accountability, and the fight against corruption in the public sector in attaining a desirable sustainable environment. It would require not just economic globalization alone, but also a better institutional quality level to push for an environmentally friendly agenda while enhancing sustainable income growth that can foster renewable energy consumption among the E7 economies.

3.4. Granger causality

The estimates from the combined panel estimators that are applied in the study may not necessarily reflect the direction of causality among the variables, thus, we provide a causality test report for the variables in the present study following the importance of this test in various empirical studies (Alola and Kirikkaleli, 2019; Amiri and Ventelou, 2012; Çoban et al., 2020; Gyamfi, Adedoyin, Bein, Bekun and Agozie, 2021c; Onifade et al., 2020; Saint Akadiri, Bekun and Sarkodie, 2019). We report the Dumitrescu and Hurlin (2012) Granger causality test for the study.

$$Y_{it} = \delta_i + \sum_{k=1}^{p}\beta_{1ik}Y_{i,t-k} + \sum_{k=1}^{p}\beta_{2ik}X_{i,t-k} + \varepsilon_{it} \tag{10}$$

From Eq. (10), β_{2ik} and β_{1ik} denote the regression coefficients and the autoregressive parameters for individual panel variable i at time t, respectively. Following the assumption of a balanced panel of observation for the variable Y_{it} and X_{it} in the study, the null hypothesis of absence of causality among variables was tested against the alternative hypothesis of heterogeneous causality in the panel observation. The Granger causality results are provided in Table A3 while an annotated diagrammatical representation of the overall empirical scheme, based on the adopted econometric outcomes is detailed in Fig. 1 in the Appendix.

From Table 6, both economic globalization and income level Granger causes carbon emission among the E7 economies. Also, carbon emission level Granger causes renewable energy consumption while there was not sufficient evidence for feedback causality among other variables.

4. Conclusion and policy direction

Following the UN-SDG-13 crusade to reduce climate change impact, this study explores this topical issue by investigating the effect of

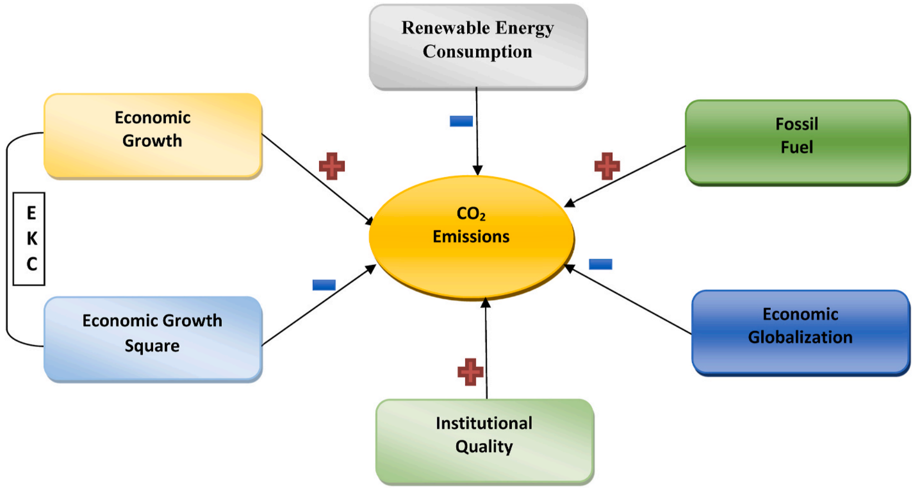

Fig. 1. Empirical scheme, based on AMG, CCEMG AND Driscoll-Kraay econometric outcomes.

Table 6
Dumitrescu and hurlin causality analysis.

	W-stat.	p-value
$LnY \rightarrow LnCO_2$	2.263***	(0.0080)
$LnCO_2 \rightarrow LnY$	1.459	(0.2360)
$LnY^2 \rightarrow LnCO_2$	1.226*	(0.0965)
$LnCO_2 \rightarrow LnY^2$	3.699**	(0.0273)
$LnI \rightarrow LnCO_2$	2.112	(0.1250)
$LnCO_2 \rightarrow LnI$	0.086	(0.9172)
$LnEG \rightarrow LnCO_2$	3.235**	(0.0424)
$LnCO_2 \rightarrow LnEG$	1.282	(0.2807)
$LnR \rightarrow LnCO_2$	0.942	(0.3921)
$LnCO_2 \rightarrow LnR$	3.011*	(0.0525)
$LnNR \rightarrow CO_2$	0.705	(0.4955)
$LnCO_2 \rightarrow LnNR$	0.583	(0.5593)

Note: ***, ** and * are 1%, 5%, and 10% significance level, respectively, while → denote does not "Granger cause".

institutional quality and renewables in the conventional EKC setting for E7 economies from 1995 to 2016. This study leverages on second-generational modeling methodology that corrects for cross-sectional dependency and heterogeneity to achieve the soundness of empirical findings. To this end, we used Augmented Mean Group, Common Correlated Effects Mean Group estimator, Driscoll-Kraay and Dumitrescu and Hurlin Causality test. The Westerlund cointegration analysis affirms the existence of a long-run bond between the study highlighted variables. That is, jointly, income level and its quadratic form, economic globalization, and institutional quality explain the extent of environmental degradation in E7 economies.

This study result affirms the EKC phenomenon in E7. The plausible explanation for this finding resonates with the bloc as emerging and industrialized economies where economic activities are operated without environmental sustainability in view. This suggests that emphasis is placed on economic expansion relative to the bloc quality of the environment. We also observed from the empirical results that fossil-fuel-based energy also contributes to dampen the environment. Furthermore, the bloc shows that the institutional level is still not sufficient to spur a clean environment. The quality of intuitional and commitment in E7 economies are weak relative to their counterpart G7 economies where rule of law and other institutional apparatus are reinforced to maintain environmental sustainability. Interestingly, our study shows that economic globalization and renewables improve the quality of the environment. This connotes that environmental consciousness is creeping into the blocs amidst a wave of global and economic interconnectedness. The need for a transition to renewables such as hydro energy, photovoltaic, biomass among others, which are known to be cleaner and ecosystem friendly, should be pursued in earnest.

This study further highlighted policy prescriptions given the study outcomes. The policy suggestion includes:

(i) The implication of the EKC in E7 means that the blocs need to minimize environmental degradation on its trajectory for increased income level. Given that these blocs are still very much emerging on their growth path, there is a need to fortify institutional apparatus to enact effective environmental strategies and regulations to achieve environmental sustainability without compromise for economic development.
(ii) The need for a transition to renewables is pertinent given the advantages of a cleaner environment. As such, there should be concerted efforts on part of all stakeholders, government officials for a paradigm shift to clean energy technologies by substituting the bloc's share of energy mix from conventional energy of fossil fuel to clean energy sources.

Conclusively, the need to reduce environmental degradation activities should be pursued by the blocs, such as tree planting activities to mitigating the effect of deforestation. This study investigated the applicability of the EKC phenomenon for E7 as a suggestion for further studies, other scholars can extend the EKC argument by accounting for covariates such as population, urbanization in an asymmetric framework for other blocs like MENA, and emerging blocs using disaggregated data. It would be helpful to examine regional results across countries and search for similarities in terms of geography, culture, religion, language, and political system. Another field of study may be cross-country comparisons between emerging and developed economies, as these vary in many ways. Finally, testing the EKC hypothesis at the regional level using endogeneity-resistant methodologies may be another research subject.

CRediT authorship contribution statement

Festus Victor Bekun: Supervision, and Corresponding. **Bright Akwasi Gyamfi:** Validation, Visualization, Data curation, analysis. **Stephen Taiwo Onifade:** Conceptualization, Formal analysis, Methodology. **Mary Oluwatoyin Agboola:** Writing – original draft, Writing, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix B. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2021.127924.

Appendix

Table A1
Description of Variables and Summary Statistics

Description of Variables

Name of Indicator	Abbreviation	Proxy/Scale of Measurement	Source
Carbon di oxide emissions per capita	CO_2	measured in metric tonnes	WDI
Income	Y	it is proxied by the gross domestic product per capita (2010 Constant USD)	WDI
Economic Globalization	EG	KOF globalization Index	(Gygli et al., 2019) https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.htm
Square of Income	Y^2	it measures the square of GDP per capita	WDI
Fossil fuel	NR	Fossil fuel energy consumption (% of total)	WDI
Renewable energy	R	Renewable energy consumption (% of total final energy consumption)	WDI
Institutional quality	I	CPIA transparency, accountability, and corruption in the public sector rating	WDI

Summary Statistics

	$LnCO_2$	**LnY**	**LnY^2**	**LnI**	**LnEG**	**LnR**	**LnNR**
Mean	13.578	8.493	5.707	2.992	3.770	2.949	4.326
Maximum	16.153	9.551	1.980	3.620	4.566	3.997	4.525
Minimum	12.055	6.514	4.551	2.230	2.749	1.171	3.938
Std. Dev.	1.083	0.860	5.027	0.359	0.356	0.898	0.186
Skewness	0.774	−0.753	0.481	−0.335	−0.922	−0.663	−0.529
Observations	154	154	154	154	154	154	154

Source: Authors' computation

Table A2
Correlation Matrix

	$LnCO_2$	LnY	LnI	LnEG	LnR	LnNR
$LnCO_2$	1					
p-value	–					
LnY	−0.334***	1				
p-value	(0.0000)	–				
LnI	0.163**	−0.276***	1			
p-value	(0.0429)	(0.0005)	–			
LnEG	−0.094	−0.327***	0.549***	1		
p-value	(0.2449)	(0.0000)	(0.0000)	–		
LnR	0.395***	0.399***	−0.268***	−0.425***	1	
p-value	(0.0000)	(0.0000)	(0.0008)	(0.0000)	–	
LnNR	0.329***	0.325***	−0.152*	−0.396***	0.659***	1
p-value	(0.0000)	0.0000	(0.0595)	(0.0000)	(0.0000)	–

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

Table A3
VIF Estimations Table

Variables	VIF	1/VIF
LnY	1.26	0.795
LnI	1.49	0.672
LnEG	1.72	0.580
LnR	1.99	0.503
LnNR	1.87	0.534
Mean VIF	1.67	

Note: the VIF estimation results confirm the absence of multi-collinearity problems as the values all fall below 10.

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