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RESEARCH ARTICLE

Accounting for the combined impacts of natural resources rent, income level, and energy consumption on environmental quality of G7 economies: a panel quantile regression approach

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Abstract

As the argument widens on the need to cut down on global carbon emissions, this study addresses environmental degradation using a combination of second-generation empirical methodologies including, quantile regression (QR), augmented mean group (AMG), fully modified ordinal least square (FMOLS), and dynamic ordinal least square (DOLS) to examine the impacts of natural resource rents alongside disaggregated energy consumption on the environmental quality of the G7 economies within the framework of the stochastic impact by regression on population, affluence, and technology (STIRPAT) model. The empirical findings reveal that the total natural resources rent indicates a positive significant relationship with pollution in all the quantiles except Q 0.05. Additionally, the findings for renewable energy consumption are adverse and significant throughout the assessed quantiles while fossil fuel energy consumption is reported to have a positive and significant effect on carbon dioxide emissions, thus, increasing environmental degradation experienced in the G7 economies. The extended findings from the Granger causality analysis also show that income levels combined with fossil fuel use have a strong effect on environmental degradation, while the total natural resources rent granger causes clean energy consumption within the G7 countries. This finding supports the assertions that natural resource revenue is mostly channeled into further productivity avenues which consequently lead to further environmental degradation. As such, while maintaining targeted revenue agenda, we strongly recommend that productivity gains from natural resource rents within the G7 economies should be harnessed for investment in clean energy for a more sustainable environment.

Keywords Total natural resource rent · Decarbonization · Renewables · Panel econometrics · G7

JEL classification C32 · Q 40 · Q43

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Introduction

Over the past few decades, the relationship between economic growth and environmental indicators like carbon emission level and ecological consumption among others has gained significant attention from researchers and policymakers. This development is not unexpected as the awareness of the growing risks and dangers of environmental degradation has started gaining momentum gradually (Chokriensukchai and Tamang 2010; Freije et al. 2017; Balsalobre-Lorente et al. 2019; Yilmaz and Can 2020; Thaker et al. 2020). Various studies are ongoing on the possible impacts of environmental degradation, and the argument on climate change and environmental challenges is expanding with respect to changes in average temperatures with concerns of more frequent extreme values, rising sea levels that are accompanied by risks of disasters like flooding posing potential threats on lives and properties, and the challenges of prolonged droughts being witnessed in some places among other issues (Meehl et al. 2009; Trenberth 2011; Trenberth 2012; Pachauri et al. 2014). Thus, addressing environmental degradation vis-à-vis researches on various pollutant emissions has taken an upward trajectory in the literature.

Some studies addressing environmental degradation within the scope of pollutant emission can be classified into three groups. The first group encompasses the studies investigating the applicability of the Environmental Kuznets Curve (EKC) hypothesis (Ozturk and Al-Mulali 2015; Churchill et al. 2018; Yilanci and Ozgur 2019; Onifade et al. 2021a; Demissew Beyene and Kotosz 2020). The second group captures studies with the EKC equations that account for the environmental impact of other factors, such as energy consumption, trade, and urbanization among others (Danish et al. 2019; Hanif et al. 2019; Sharif et al. 2019; Chen et al. 2019; Destek and Sinha 2020; Ulucak and Ozcan 2020; Anwar et al. 2021; Onifade et al. 2021b). While the third group is those that specified the relationship between economic growth and carbon emissions without necessarily accounting for the predictions of the EKC hypothesis (Bekun et al. 2019; Nathaniel and Iheonu 2019; Mahalik et al. 2020).

The identified groups of studies have been carried out using several sample countries mainly in group analysis (Erdogan et al. 2020; Ulucak and Ozcan 2020; Bekun et al. 2021a; Shahbaz et al. 2018; Bekun et al. 2021b), but with few cases of country specify analysis (Ozturk and Al-Mulali 2015; Alola and Ozturk 2021). However, the current study set out to harness the focus points of all of the identified groups to analyze the unique case of the G7 economies as the bloc strategizes on ways to enhance environmental quality.

At the moment, pollutant emission remains high among the G7 economies as countries like the USA account for about 13% of the global greenhouse gas (GHG) emission being the second top-emitting country in the world (UNEP 2018). Also, as of 2017, emission from the European Union (EU) bloc accounts for about 9% of the global GHG emission (UNEP 2018), and major G7 members in the EU like Germany, France, Italy, and the UK have their important share in the bloc's contribution to the global emission level. Therefore, the subject of mitigating environmental damage in the G7 nations is still open to further discussion.

Hence, in the current work, the EKC equation is extended to account for the environmental impact of energy consumption while incorporating natural resource rents in the framework of the stochastic effect by analysis on population, affluence, and technology (STIRPAT) model for the Group of Seven (G7) economies including Canada, France, Germany, Italy, Japan, the UK, and the USA. The strength of the current study lies in the aggregation of the approaches from the aforesaid three groups of study to address problems of degradation in the level of environmental quality for the case of the G7 economies using a combination of second-generation empirical methodologies.

The study has been outlined into 5 sections starting with the introduction in Sect. 1 and an up-to-date review of extant studies in Sect. 2. The methodology and data were discussed in Sect. 3, while Sect. 4 and 5 contain the discussion of the empirical results and the policy implications accordingly.

Review of related literature

Some existing studies have taken steps toward extending the frontier of energy research beyond the EKC hypothesis for a different group of countries by covering varying sample periods with empirical results providing mixed conclusions. Bekun et al. (2019) examined the nexus between CO_2 emissions, economic growth, resource rent, non-renewable, and renewable energy consumption during the period 1996–2014 using a balanced panel data of 16 European Union countries. The results from the study show that economic growth, resource rent, and non-renewable energy contribute to growth in carbon emissions in these countries, whereas the use of renewable energy mitigates the challenge. The study also identified feedback in the causality between economic growth and CO_2 emissions as well as for non-renewable, renewable energy consumption, and CO_2 emissions. For natural resource rent, a unidirectional causality runs to CO_2 emissions. Nathaniel and Iheonu (2019) considered the condition in developing economies during the period 1990–2014 using a sample consisting of 19 African countries. The results affirm the environmental deterioration effect of non-renewable energy and also support the growing evidence that renewable energy mitigates CO_2 emissions. Another interesting result from the analysis is a unidirectional causality that runs from both renewable and non-renewable energy sources to CO_2 emissions in these developing economies.

Using an extended EKC model and a global sample of 74 countries from 1990 to 2015, Sharif et al. (2019) confirmed a significant positive relationship between non-renewable energy use and CO_2 emissions and a significant negative relationship between renewable energy and CO_2 emissions. The results also confirmed the validity of the inverted U-shaped relationship of the EKC hypothesis for the sampled counties. Further evidence from Hanif et al. (2019) using an extended EKC model for the environmental condition in the developing Asian economies covered the period 1990–2015 and used data from 25 countries. The results confirmed the validity of the inverted U-shaped curve and further heightened the environmental deterioration effect of non-renewable energy consumption and natural resource depletion and the carbon mitigation effect of renewable energy use. Assessing environmental impact based on CO_2 emissions in the BRICS countries during the period 1990–2015, Danish et al. (2019) confirmed the EKC hypothesis, but not valid in India and also showed that natural resource rent mitigates environmental challenges in Russia but degrades the environment in South Africa, while renewable energy use has significant mitigation effect in Brazil, China, India, and Russia but not in South Africa. Results from more recent studies are not different. Erdogan et al. (2020) examined an extended EKC model using a sample of 25 OECD countries during the period 1990–2014. The results failed to validate the EKC hypothesis for the sampled countries but confirmed the environmental disregarding impact of non-renewable energy and the carbon mitigation effect of renewable energy in OECD countries. In another study for CO_2 emissions in the OECD countries, Ulucak and Ozcan (2020) showed that a valid U-shaped relationship however exists for the environmental impact of economic growth for the period 1980–2016. The study also confirmed the environmental degrading effect of non-renewable energy use and natural resource rents but surprisingly showed that renewable energy use had no significant mitigation effect in the OECD countries during the period 1980–2016.

In another study for the BRICS countries, Mahalik et al. (2020) modeled the environmental impact of a number of factors using data from 1990 to 2015. The empirical results from the analysis showed that non-renewable energy sources and economic growth contribute significantly to the rising CO_2 emissions, whereas renewable energy use reduces the environmental challenge. Employing an extended EKC framework, Anwar et al. (2021) examined the environmental impact of renewable and non-renewable energy in the ASEAN countries during the period 1990–2018. Based on quantile regression analysis, the study showed that non-renewable energy use contributes to CO_2 emissions in all the countries, whereas renewable energy use has a significant mitigation effect in countries at the lower quantiles of CO_2 emission distribution. The study also verified the validity of the inverted U-shaped relationship (i.e., the EKC hypothesis) for the countries. In the particular case of the USA, Pata (2020) observed the inverted U-shaped EKC relationship for the environmental impact of economic complexity for the period 1980–2016. The study also identified the environmental deterioration effect of non-renewable energy use and the carbon mitigation effect of renewable energy use given the process of economic expansion over time.

However, Gyamfi et al. (2021a) contribute to this field by studying the effect of biomass energy use on carbon dioxide emissions in the framework of the G7 economies. Thus, they used energy consumption and GDP as a proxy for economic growth, which includes aspects that can affect emissions, for annual periods throughout 1995 and 2016 in the context of G7 economies. The current study contributes to the existing literature by evaluating the influence of biomass energy on emissions using novel econometric methodologies such as panel cross-section augment auto-regressive distributive lag (ARDL) and common correlated estimate mean group (CCEMG). The empirical evidence from all methodologies indicates that biomass energy use is significantly and adversely correlated with CO_2 pollution implying that it contributes to long-term pollution reduction. On the other side, a substantial positive association exists between energy usage and pollutants, showing that fundamental energy use is not sustainable for the ecosystem over the investigated period. Finally, the findings established that GDP increases CO_2 emissions, in the long run, relative to the G7. Thus, the growth-induced pollution hypothesis is validated in the G7 blocs. Moreover, in the study of Bildirici and Gökmenoğlu (2017), the purpose was to analyze the connection between environmental degradation, economic growth, as well as hydroelectric energy use in the various business cycles regimes for the G7 economies from 1961 to 2013. They accomplished this objective by utilizing Markov switching-vector autoregressive (MS-VAR) and MS-Granger causality approaches, as typical methods investigate causality by presuming all periods are equal in level. In contrast to conventional methods, these techniques enable the determination of the connection and casual dynamics among elements in distinct domains. The causation findings for various regimes aided in the formulation of policy proposals for each jurisdiction separately. According to the analytical findings, there is a bidirectional Granger causal relationship between carbon dioxide emissions and economic growth in both the catastrophe and high development regimes, whereas carbon dioxide emissions are the Granger cause of economic growth in all dictatorships. They found proof that hydropower energy use is a Granger cause of economic growth overall, although some G7 countries exhibit bidirectional causality. The study conducted by Hao et al. (2021) examines the role of green growth in ensuring environmental sustainability. Their study examined the effect of ecologically adapted multifactor productivity gains (also known as green growth) on CO_2

emissions in the G7 from 1991 to 2017. The study employs a method(s) for second-generation panel data, namely the cross-sectionally augmented auto-regressive distributive lag (CS-ARDL) model. Theoretical and empirical evidence implies that green growth, both linear and non-linear, reduces CO_2 emissions. Additionally, environmental taxes, human capital development, and the usage of renewable energy are shown to reduce CO_2 emissions. GDP growth has a negative influence on the ecology in both the short and long run. Nevertheless, their finding confirms the theoretical proposition that green growth improves the ecological balance. Nevertheless, Pata and Yilanci's (2020) article investigates the dynamic links involving financial development, globalization, energy consumption, economic growth, and ecological footprint in the G7 economies from 1980 to 2015. Globalization, according to long-run projections, decreases Canada's and Italy's ecological footprint, whereas financial development reduces pollution in Japan. Additionally, the findings indicate that increased energy use contributes to ecological damage in these three countries. Additionally, the causality test using a partial frequency adaptable Fourier function suggests that globalization produces an ecological footprint in all G7 countries except France, whereas financial development causes an ecological footprint in France, Japan, and the UK. Finally, the aggregate findings indicate that globalization is a more effective instrument for regulating the G7 countries' ecological footprint than financial development.

Methodology

The variables and data

Unlike previous analysis that investigates the effects regarding energy intake and ecological consequences using a variety of macroeconomic and energy factors (see Adedoyin et al. 2020; Gyamfi et al. 2020a), this analysis investigates the mechanisms by which energy from atmospheric carbon pollution impacts the connection among income, the square of income, natural resources, fossil fuel, and renewable energy in the carbon-income-environmental relationship for the G7 economies from 1990 to 2016. Table 1 below provides a detailed explanation for the elements utilized in this analysis.

Methodology

We employed the cross-section dependence (CD) methods to determine the appropriate methodological technique(s) for this analysis. The CD technique results assist in determining whether to use 1st-generation or 2^{nd}-generation panel data estimation methods. If the CD assessment is not performed, the study can be biased, irrelevant, and contradictory (Dong et al. 2018; Gyamfi et al. 2021b). To guarantee that the above complications do not arise, the researchers conducted a robustness review using three CD assessments: the Pesaran (2007) CD technique, the Breusch and Pagan (1980) LM technique, as well as the Pesaran (2015), scaled LM technique. Considering that the time span (T) of this dataset is greater than the volume of cross sections (N), more emphasis was put on the scaled LM test by Pesaran (2015). Equation 1 illustrates the CD test approximation.

$$\mathrm{CD} = \sqrt{\left(\frac{2T}{N\left(N-1\right)}\right)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{p}_{ij}\right) \tag{1}$$

Whereas from Eq. 1, $\widehat{p}_{ij}$ captures the variables of the remaining ADF evaluation with respect to the pairwise cross-sectional connection. T and N are the model and panel range distinctly for the cross-sectional as well as the time period.

The stationarity technique

The approximation evidence of CD reveals the incompetence of the 1^{st}-generation unit root approach (e.g., Im et al. 2003). As a result, the researchers used a 2^{nd}-generation unit root approach (CIPS) to address the issue of assessment inefficiency. According to Pesaran (2007), the preceding cross-sectional augmented Dickey-Fuller (CADF) analysis is used:

$$\begin{aligned}\Delta \mathrm{Y}_{it} = {} & \varphi_i + \rho_i^{*}\mathrm{Y}_{i,t-1} + d_0\overline{\mathrm{Y}}_{t-1} + \sum_{j=0}^{p} d_{ij}\Delta\overline{\mathrm{Y}}_{t-j} \\ & + \sum_{j=1}^{p} c_{ij}\Delta Y_{i,t-j} + \varepsilon_{it}\end{aligned} \tag{2}$$

where Δ shows first differences, Y is analyzed variable, $\overline{\mathrm{Y}}_t$ is the average at time t of all N observations, ε_{it} presents the error term. After running this CADF regression for each unit i in the panel, the CIPS statistics can be calculated by the following equation:

$$\mathrm{CIPS} = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{3}$$

A second-generation cointegration test is performed in the proximity of first differences stationary variables, to assess the long-run effects of the factors under consideration.

The cointegration technique

The study utilized the Westerlund (2007) method to attain evidence of cointegration among the coefficients. The error rectification method (ECM) of the estimation is presented as

$$\begin{aligned}\Delta Y_{it} = {} & \delta_i' d_t + \phi_i Y_{it-1} + \lambda_i' X_{it-1} + \sum_{j=1}^{pi}\phi_{ij}\Delta Y_{it-j} \\ & + \sum_{j=0}^{pi}\gamma_{ij}\Delta X_{it-j} + \varepsilon_{it}.\end{aligned} \tag{4}$$

Table. 1 Description of variables

Name of indicator	Abbreviation	Proxy/scale of measurement	Source
Carbon dioxide 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
Total natural resources rent	TNRR	% of GDP	WDI
Square of income	Y^2	It measures the square of GDP per capita	WDI
Fossil fuel	FF	Fossil fuel energy consumption (% of total)	WDI
Renewable energy	R	Renewable energy consumption (% of total final energy consumption)	WDI

Thus, $\delta_t = (\delta_{i1}, \delta_{i2})$, $dt = (1, t)'$, and ϕ are the vector of parameters, deterministic mechanisms, as well as the error correction factors accordingly. By obtaining the presence of cointegration, four tests were examined. These four tests were built in line with the OLS approach of the parameter (ϕi) in the third equation. There were two Group mean statistics techniques which are presented as

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\widehat{\propto}_i}{\mathrm{SE}\left(\widehat{\propto}_i\right)} \tag{5}$$

$$G_\propto = \frac{1}{N}\sum_{i=1}^{N}\frac{T\widehat{\propto}_i}{\widehat{\propto}_i(1)}. \tag{6}$$

Thus, $\widehat{\propto}_i$ represents $\mathrm{SE}(\widehat{\propto}_i)$ which is the standard error. On the other hand, the given semiparametric kernel test of the parameter $\propto_i(1)$ is $\widehat{\propto}_i(1)$. The overall panel can be said to be cointegrated as indicated in the remaining techniques in Eqs. 7 and 8:

$$P_\tau = \frac{\widehat{\propto}}{\mathrm{SE}\left(\widehat{\propto}\right)} \tag{7}$$

$$P_\propto = T\widehat{\propto}. \tag{8}$$

Quantile regression (QR), augmented mean group (AMG), fully modified ordinal least square (FMOLS), and dynamic ordinal least square (DOLS)

The study uses the QR technique, the AMG, the FMOLS, and the DOLS technique. The presence of cointegration makes a long-term linkage assessment via the AMG, FMOLS, and DOLS econometrically rational. The AMG, FMOLS, and DOLS models have the unique ability to accommodate cross-sectional dependence and slope heterogeneity. Nonetheless, the QR was preferred as the statistical instrument over the OLS for a variety of factors. The default dissemination and perhaps even the expected mean of zero in the OLS sums of error principle are somewhat impractical, given that economic indicators may have numerous distribution methods (De Silva et al. 2016). The QR exacerbates this deficiency (Salman et al. 2019; Gyamfi et al. 2021a). Besides, as observed by Zhu et al. (2016), the technique (QR) makes no assumptions about the period's work, while according to Bera et al. (2016), the estimates can also appear stable in the presence of exceptions. No delivery forecasts were already created (Sherwood and Wang 2016). We provide a framework for the approach as expressed in Eq. 9.

$$\mathrm{Quant}_\theta\ (y_i/x_i) = x\beta_\theta + \mu_\theta, 0b\theta 1 \tag{9}$$

Whereas x represents explanatory variables and y represents endogenous variables. The specific element's equilibrium point and disturbance term are concurrently θth as well as μ. We employ contingent quantile regression to analyze the influence of the explanatory variables that will be employed in our empirical study on the basis of the initial scaling factor. The QR method has been used previously in many studies such as Nathaniel et al. (2020), Gyamfi et al. (2021c), among others.

STIRPAT model

This study is built upon this stochastic effect by inference on population, affluence, and technology (STIRPAT) framework. According to the STIRPAT theory, environmental degradation does have economic and social impacts.

$$I_{\mathrm{t}} = \vartheta_o P_t^{\xi 1}\, A_t^{\xi 2}\, T_t^{\xi 3}\, \mu_t \tag{10}$$

Based on Eq. 8, I denotes environmental deficiency, while P represents the population. On the other hand, A is for affluence, while the level of technology is denoted by T. The error term is μ while ξ^1–ξ^3 are the element assessors. The level of technology (T) can be subdivided according to the analysis' objective (Anser 2019; Gyamfi et al. 2021c). I classifies the environmental variables in this study as mentioned previously based on the review of Solarin and Al-Mulali (2018). In

Table. 2 Summary statistics

	CO_2	Y	TNRR	R	FF
Mean	2.3006	10.5824	−1.5905	1.8304	4.3582
Median	2.2444	10.5824	−1.9293	1.7810	4.4221
Maximum	3.0046	10.8713	1.6738	3.1224	4.5500
Minimum	1.5202	10.2503	−4.5254	−0.4971	3.8335
Std. dev.	0.3982	0.1361	1.6758	0.8681	0.1791
Skewness	0.2737	−0.0668	0.1444	−0.5374	−1.6256
Kurtosis	2.0163	2.5096	1.8233	2.9998	4.4620
Jarque-Bera	9.9798	2.0343	11.5589	9.0971	100.0824
Probability	0.0068	0.3616	0.0030	0.0105	0.0000
Number of observations	189	189	189	189	189

another context, P and A are represented by sustainable development, income, and income squared, accordingly. The writers then embraced natural resources rent (TNRR), renewable energy utilization (R), and fossil fuel intake (FF) as a representation of T. The stretched plan is presented in Eq. 11.

$$I_t = \vartheta_o Y_t^{\xi 1}\, {Y2}_t^{\xi 2}\, \mathrm{TNRR}_t^{\xi 3}\, R_t^{\xi 4}\, \mathrm{FF}_t^{\xi 6}\, \mu_t \tag{11}$$

To accomplish the analysis' objective, this area introduces the frameworks that demonstrate how each of the controlling factors used in the analysis impacts the explanatory factor (carbon pollution). To ensure that the robust vector results are interpreted as elasticity, all factors are expressed in their logarithmic forms (ln). The function is further simplified as seen in Eq. 12 by getting the logarithm from each of the factors.

$$\begin{aligned}\ln I_t = \vartheta o + \xi_1 \mathrm{Ln}Y_t + \xi_2 \mathrm{Ln}{Y^2}_t + \xi_3 \mathrm{LnTNRR}_t \\ + \xi_4 \mathrm{Ln}R_t + \xi_5 \mathrm{LnFF}_t + \mu_t\end{aligned} \tag{12}$$

From Eq. 12, the variables Y, Y^2, TNRR, R, and FF denote income, square of income, total nature resources rent, renewable energy intake, and fossil fuel intake. I, however, denotes the ecological factor utilized in this study, which is CO_2 emission levels. The authors formulated Eq. 13 to analyze the impact of Y, Y^2, TNRR, R, and FF on I in their normal log equation at the selected quantile levels.

$$\begin{aligned}Q\tau\,(\mathrm{LnCO_2}) = \vartheta\tau + \xi_{1\tau}\mathrm{Ln}Y_{it} + \xi_{2\tau}\mathrm{Ln}Y2_{it} \\ + \xi_{3\tau}\mathrm{LnTNRR}_{it} \\ + \xi_{4\tau}\mathrm{Ln}R_{it+}\ \xi_{5\tau}\mathrm{LnFF}_{it+}\ \mu_t\end{aligned} \tag{13}$$

From Eq. 11, while the outstanding coefficients preserve their unique description, CO_2 represents the carbon dioxide pollution level. The locus idea is τ based on the explicative factors. $Q\tau$ parallels to the τth distributional stage regression evaluation which can be obtained by applying the method in the twelfth equation (Eq. 14).

$$Q_\tau = \arg\min_{Q_\tau} \sum_{k=1}^{q} \sum_{t=1}^{T} \sum_{i=1}^{N} \left(\left| y_{it-}\alpha_{i-}x'_{it}Q_\tau \right| w_{it} \right) \tag{14}$$

where q, T, N, and w_{it} stand for the number of quantiles, years, cross sections, and weight of the ith country in the ith year respectively.

Table. 3 Correlation outputs

	CO_2	Y	TNRR	R	FF
CO_2	1				
p value	-				
Y	0.3881***	1			
p value	(0.0000)	-			
TNRR	0.6563***	0.1434**	1		
p value	(0.0000)	(0.0490)	-		
R	0.1024	0.3882***	0.2005***	1	
p value	(0.1605)	(0.0000)	(0.0057)	-	
FF	0.4173***	−0.0355	0.1625**	−0.4683***	1
p value	(0.0000)	(0.6271)	(0.0255)	(0.0000)	-

*<0.01; **<0.05; ***<0.10

Empirical results and discussion

This study begins with some preliminary empirical analysis and captures the variables used and reports the descriptive statistics in Table 2 as being normally distributed. From the summary statistics, there is a considerable gap between the minimum and maximum values for the period in view. From the table, it was observed that income has the highest mean, median, and maximum, followed by fossil fuel, while total natural resource rent has the lowest mean, median, and maximum from the outcomes. Table 3 then shows the outcomes of

Table. 4 Cross-sectional dependency (CD) test results

Model	Pesaran (2007) CD test	Pesaran (2015) LM test	Breusch and Pagan (1980) LM test
$CO_2 = f(Y, Y^2, \text{TNRR}, R, \text{FF})$	5.140***	−2.055**	697.45***
p value	(0.0000)	(0.040)	(0.0000)

*<0.01; **<0.05; ***<0.10

the correlation of the variables. It was observed that pollution has a positive correlation with income, total nature resource rent, and fossil fuel in a significant form. Income on the other hand has a positive and significant relationship with total nature resources rent and clean energy. Total natural resources proves to be positively significant with clean energy and fossil fuel, while renewable energy has a negative correlation with fossil fuel.

Estimated results

The cross-sectional dependency analysis findings are presented in Table 4, which illustrates a reason for rejecting the null assumption of an unbiased cross section of the factors under examination. In brief, the factors being studied are cross-sectional in nature.

Table 5 reports the second-generation panel unit root test designed to account for the order of integration of the variables under consideration. The cross-sectionally augmented IPS (CIPS) panel unit root test as proposed by Pesaran (2007) does not necessarily require the estimation of factor loading to eliminate cross-sectional dependence rather augmenting it to include the lagged cross-sectional mean, and its first difference is necessary and sufficient to capture the cross-sectional dependence that arises through a single-factor model. We observe from Table 5 that income squared (under the CIPS panel) is the only variable that is significant at the level at 10% level of significance. However, the rest of the variables in both methods of the stationarity test are significant at the I(1) at 1% and 5% levels of significance accordingly. The results reported in Table 5 support the presence of unit root in all the variables listed under review.

The outcomes acquired from the cointegration examination in Table 6 led us to the presentation of the suitable assessment methods, in the form of QR, AMG, FMOLS, and DOLS.

The outcomes from the QR, AMG, FMOLS, and DOLS regressions for the long-run association regarding CO_2 and the regressors are shown in Table 7 whereby this analysis will rely mainly on the findings from the QR.

All the three estimation techniques, that is, AMG, FMOLS, and DOLS, ideated that there is an inverted U-shape for the G7 economy which indicates that income has a positive significant relationship with pollution, but its square has a negative relationship with pollution in the long run. Again, total natural resource rent has a positive significant relationship with pollution. However, renewable energy has a negative relationship with pollution, while fossil fuel has a positive significant relationship with pollution in all the three estimations used as a sensitivity.

The quantile regression analytical outcome (demonstrate in Table 7) presented that income negatively influences pollution at the early stages (Q.05 and Q.25) but positively affected pollution at the later stages (Q.75 and Q.95). This shows that higher income in the G7 economies is a factor in the region's economic degeneration, as evidenced by the unchecked development of the factories that lead the most to environmental damage as they develop. Again, the square of income result shows a negative significant relationship with pollution across all the quantiles. This is an indication of an inverse U-shaped relationship between these variables under review. The result of a positive and

Table. 5 Panel IPS and CIPS stationarity techniques

Factors	CIPS				IPS			
	I(0)		**I(1)**		**I(0)**		**I(1)**	
	C	**C&T**	**C**	**C&T**	**C**	**C&T**	**C**	**C&T**
CO_2	−2.165	−2.563	−4.967***	−5.325***	−0.654	−1.917	−5.809***	−6.299***
Y	−1.159	−1.217	−3.377***	−3.409***	−0.909	−1.799	−4.039***	−4.099***
Y^2	−1.308	−0.987	−3.260***	−3.290***	−0.696	−1.822	−4.037***	−4.055***
NTRR	−2.529	−3.123	−5.016***	−5.055***	−1.940	−2.487	−4.881***	−4.872***
R	−2.090	−3.447	−6.022***	−5.799***	−0.944	−2.077	−4.911***	−4.883***
FF	−1.744	−1.903	−4.571***	−4.516***	−0.954	−1.958	−4.600***	−4.497***

*<0.01; **<0.05; ***<0.10

Table. 6 Westerlund (2007) cointegration test

Statistics	Value	*p* value
$G\tau$	−1.583**	(0.045)
$G\alpha$	−4.641*	(0.093)
$P\tau$	−2.542*	(0.077)
$P\alpha$	−4.369*	(0.089)

*<0.01; **<0.05; ***<0.10

The significance is 10% statistical rejection level

significant effect of income per capita on carbon emissions and the negative and significant values of income per capita square support the EKC hypothesis which affirms the study of Chen et al. (2019) for China, Ghana (Solarin et al. 2017), Indonesia (Kurniawan and Managi 2018), and Pakistan (Rahman et al. 2019) but in contrary to that of Lin et al. (2016) for China. However, total natural resource rent indicates a positive significant relationship with pollution in all the quantiles except Q 0.05. This implies that income earned on raw material extraction and processing deteriorates the quality of the environment among G7 member states. This finding is in line with prior assertions that natural resource revenue is mostly channeled into further productivity avenues that could enhance more degradation of the environment. This is in line with conclusions from Adedoyin et al. (2020) on transition economies. Additionally, the findings for renewable energy consumption are adverse and statistically significant across the estimated quantiles. This assumes that increasing sustainable energy use would mitigate the environmental deterioration associated with G7 economies. These outcomes correspond with the results of Hanif et al. (2019) and that of Danish et al. (2019) for Asian countries and the BRICS economies collectively. Lastly, fossil fuel energy consumption is reported to have a positive and significant effect on carbon dioxide emissions. This suggests that fossil fuel consumption increases environmental degradation in the G7 economies, thus, affirming the finding of Gyamfi et al. (2020b) and Asiedu et al. (2021).

Dumitrescu and Hurlin (DH) causality estimation

The Dumitrescu and Hurlin panel causality test is reported in Table 8. The panel causality experiment is needed to determine Granger non-causality in a heterogeneous panel dataset by shifting from dependent to independent variables as formulated in Dumitrescu and Hurlin's (2012) research. The applications of causality tests have been widely reported in empirical studies (Danish et al. 2019; Shahbaz et al. 2018; Onifade et al. 2020; Sharif et al. 2020; Çoban et al. 2020; Bekun et al. 2021c; Taiwo et al. 2020). From the analysis, it was observed that income and income square have a unidirectional causality relationship with pollution in the G7 economies. But renewable energy has a bidirectional relationship with pollution. However, income, income square, and total natural

Table. 7 QR, AMG, FMOLS, and DOLS outcomes for a long-run association

	Q.05	Q.25	Q.50	Q.75	Q.95	AMG	FMOLS	DOLS
Dependent variable: CO_2								
Y	0.0017***	0.0016***	0.0031	0.0018***	0.0013***	0.0022**	2.23E−05**	7.49E−05***
p value	(0.005)	(0.003)	(0.689)	(0.000)	(0.000)	(0.028)	(0.0027)	(0.0024)
*Y*2	−2.53e−0***	−2.34e−0***	−6.88e−1**	−2.08e−0***	−1.47e−0***	−2.03e−1*	−2.93E−1*	−9.22E−1***
p value	(0.001)	(0.001)	(0.043)	(0.000)	(0.000)	(0.084)	(0.0772)	(0.0025)
TNRR	0.0211	0.0920***	0.1388***	0.1601***	0.1674***	0.0687*	0.0429***	0.0496*
p value	(0.203)	(0.000)	(0.000)	(0.000)	(0.000)	(0.067)	(0.0012)	(0.0988)
R	−0.1000***	0.0107	−0.0133	−0.0360	−0.0415***	−0.0428*	−0.1335***	−0.1773***
p value	(0.009)	(0.749)	(0.779)	(0.209)	(0.007)	(0.078)	(0.0000)	(0.0000)
FF	0.4495***	0.6064***	0.7100***	1.0489***	1.2548***	1.1114***	0.6558***	0.812280***
p value	(0.009)	(0.000)	(0.001)	(0.000)	(0.000)	(0.003)	(0.0000)	(0.0006)
R^2/pseudo R^2	0.3727	0.4176	0.4047	0.5467	0.5398		0.9872	0.9981
Adj. R^2							0.9864	0.9939
Observation	189	189	189	189	189	189	189	189
Wald test						12.94**		
p value						(0.0240)		
No. regressors	5	5	5	5	5	5	5	5
No. group	7	7	7	7	7	7	7	7

*<0.01; **<0.05; ***<0.10

The significance is 10% statistical rejection level

Table. 8 The DH Granger causality evidence_

	W-stat.	Zbar-stat.	*p* value	Causality flow
$Y \rightarrow CO_2$	4.685***	2.623	(0.0087)	$Y \rightarrow CO_2$
$CO_2 \rightarrow Y$	2.275	0.057	(0.9544)	
$Y^2 \rightarrow CO_2$	4.694***	2.632	(0.0085)	$Y^2 \rightarrow CO_2$
$CO_2 \rightarrow Y^2$	2.166	−0.058	(0.9530)	
$\mathrm{TNRR} \rightarrow CO_2$	3.474	1.333	(0.1825)	$\mathrm{TNRR} \neq CO_2$
$CO_2 \rightarrow \mathrm{TNRR}$	3.404	1.259	(0.2079)	
$R \rightarrow CO_2$	7.891	6.037	(0.1233)	$R \neq CO_2$
$CO_2 \rightarrow R$	4.965	2.921	(0.3435)	
$\mathrm{FF} \rightarrow CO_2$	3.198**	1.039	(0.0087)	$\mathrm{FF} \leftrightarrow CO_2$
$CO_2 \rightarrow \mathrm{FF}$	3.248**	1.093	(0.0043)	
$Y^2 \rightarrow Y$	2.320	0.104	(0.9165)	$Y^2 \neq Y$
$Y \rightarrow Y^2$	2.389	0.177	(0.8589)	
$\mathrm{TNRR} \rightarrow Y$	3.718	1.593	(0.1110)	$\mathrm{TNRR} \neq Y$
$Y \rightarrow \mathrm{TNRR}$	3.750	1.627	(0.1035)	
$R \rightarrow Y$	2.916	0.738	(0.4599)	$Y \rightarrow R$
$Y \rightarrow R$	4.3409**	2.256	(0.024)	
$\mathrm{FF} \rightarrow Y$	3.615	1.483	(0.1379)	$\mathrm{FF} \neq Y$
$Y \rightarrow \mathrm{FF}$	3.223	1.066	(0.2862)	
$\mathrm{TNRR} \rightarrow Y^2$	3.698	1.572	(0.1159)	$\mathrm{TNRR} \neq Y^2$
$Y^2 \rightarrow \mathrm{TNRR}$	3.595	1.462	(0.1436)	
$R \rightarrow Y^2$	2.689	0.497	(0.6185)	$Y^2 \rightarrow R$
$Y^2 \rightarrow R$	4.573**	2.503	(0.0123)	
$\mathrm{FF} \rightarrow Y^2$	3.519	1.381	(0.1671)	$Y^2 \neq \mathrm{FF}$
$Y^2 \rightarrow \mathrm{FF}$	3.177	1.017	(0.3091)	
$R \rightarrow \mathrm{TNRR}$	2.233	0.011	(0.9908)	$\mathrm{TNRR} \rightarrow R$
$\mathrm{TNRR} \rightarrow R$	3.817*	1.698	(0.0894)	
$\mathrm{FF} \rightarrow \mathrm{TNRR}$	3.659	1.530	(0.1258)	$\mathrm{FF} \neq \mathrm{TNRR}$
$\mathrm{TNRR} \rightarrow \mathrm{FF}$	2.662	0.468	(0.6393)	
$\mathrm{FF} \rightarrow R$	5.406***	3.391	(0.0007)	$\mathrm{FF} \leftrightarrow R$
$R \rightarrow \mathrm{FF}$	6.412***	4.462	(8.E−06)	

*<0.01; **<0.05; ***<0.10

resources rent have unidirectional causality with clean energy. Nevertheless, fossil fuel has a bidirectional causality with clean energy. In essence, fossil fuel contributes strongly to the environmental degradation within the region. The quantile-on-quantile diagrams are presented with a summary highlighted in Figure 1 in the appendix section while for the direction of the Granger causality in the Appendix, i.e., Figure 2.

Conclusion and policy implications

This study addresses environmental degradation in the Group of Seven (G7) economies including Canada, France, Germany, Italy, Japan, the UK, and the USA using a combination of second-generation empirical methodologies. The environmental impact of energy consumption was examined with natural resource rents in these countries within the framework of the stochastic impact by regression on population, affluence, and technology (STIRPAT) model. From the analysis, among the strong impacting factors of environmental degradation within the G7 countries are the income levels and fossil energy consumption. Besides, both the income levels and the total natural resources rent Granger cause the level of renewable energy consumption among the G7 countries.

Incisively, while the latter variable was observed to be a significant driver of better environmental quality through its negative impacts on the level of carbon emission among the G7 countries, the total natural resources rent was found to be having significant positive effects on carbon emission level. As such, it is concluded that resource rent rather than enhancing the quality of the environment has a detrimental impact on the push for environmental quality in the G7 economies as such revenues are often reinvested for expansion of production base of the rent generating non-renewable sources for more revenues. The implication is that policymakers in the G7 nations need to strategize more on the implementation of the needed incentives for investment in green energy such as tax incentives while making more effort to ensure thriving conditions for clean energy investors. This will not only go a long extent in motivating new investments in clean energy but also encourage existing giant investors in non-renewable energy sources such as coal and fossil fuel source to gradually shift their attention toward green energy investments, thus, enhancing the actualization of critical goals for the development of renewable energy goals and targets for a sustainable environment via a lower carbon emission for each nation of the G7.

Additionally, the G7 should discourage assistance for coal mining, fossil fuel-based energy, and fossil fuel use. There is a necessity to reduce fossil fuel exploration & development subsidies, which have added significantly to carbon emission in the G7 economies. The construction of extremely toxic coal plants in the G7 countries has resulted in a rise in CO_2 emissions over time. The G7 countries must provide incentives for renewable energy sources. This would enable the G7 countries in achieving energy transition plans in the coming years. Furthermore, fiscal supports are needed for sustainable energy development in the G7. Thus, billion-dollar incentives for fossil fuel drilling and development can be replaced with incentives to phase out coal mining, fossil fuel-based electricity, and fossil fuel usage. Making sufficient budgetary allocations available for renewable energy development is a key to sustainable energy transition in the G7 since natural resource abundance can aid in pollution reduction, while the shortage of resources has a detrimental effect on the environment in the G7 countries.

Appendix

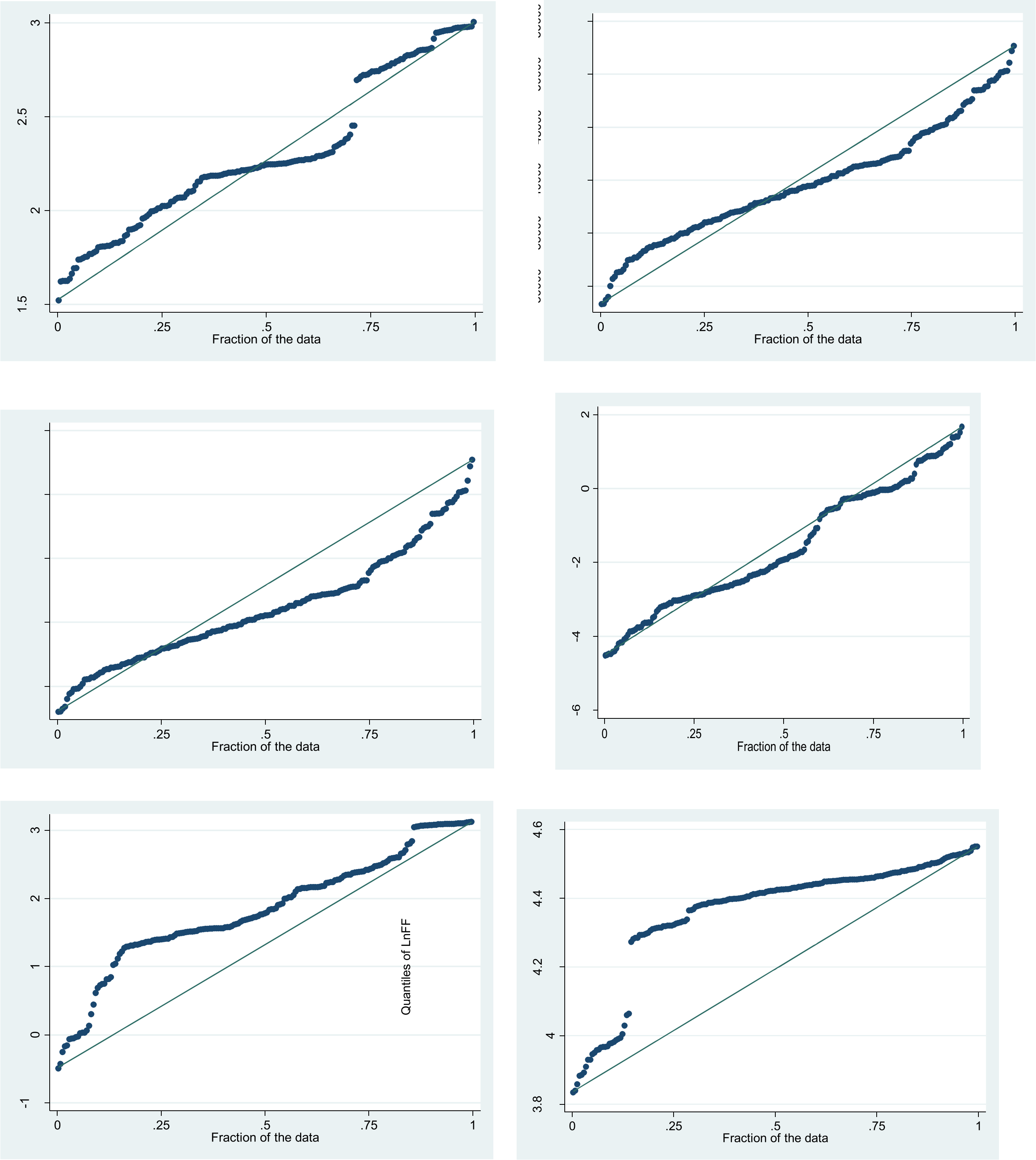
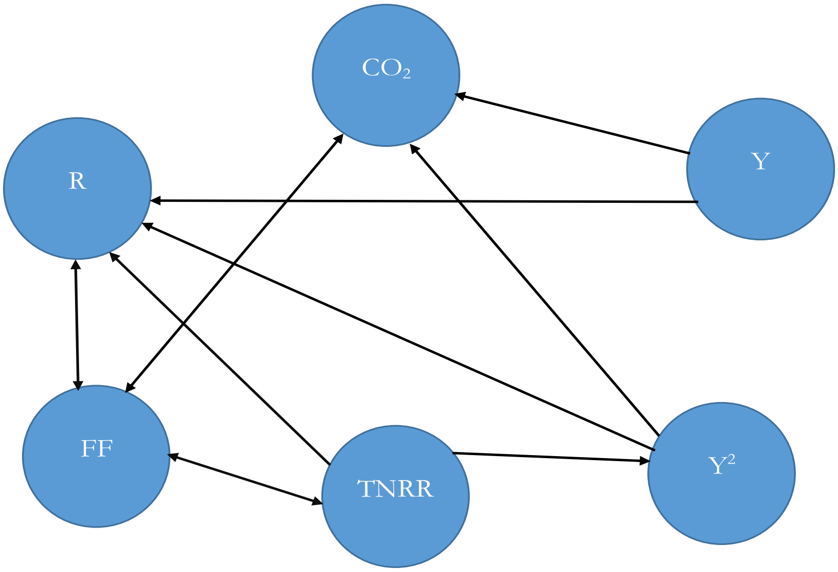


Fig. 1 Quantile on quantile diagrams

Fig. 2 DH causal relationship



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Author contribution BAG was responsible for the conceptual construction of the study's idea. STO and CN handled the literature section, while FVB managed the data gathering and preliminary analysis and was responsible for proofreading and manuscript editing.

Data availability The data for this present study are sourced from WDI as outlined in the data section.

Declarations

Ethics approval Authors mentioned in the manuscript have agreed for authorship read and approved the manuscript and given consent for submission and subsequent publication of the manuscript.

Consent to participate Not applicable.

Consent for publication Applicable.

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References

Adedoyin FF, Alola AA, Bekun FV (2020) An assessment of environmental sustainability corridor: the role of economic expansion and research and development in EU countries. Sci Total Environ 713: 136726. https://doi.org/10.1016/j.scitotenv.2020.136726

Alola AA, Ozturk I (2021) Mirroring risk to investment within the EKC hypothesis in the United States. J Environ Manag 293:112890

Anser MK (2019) Impact of energy consumption and human activities on carbon emissions in Pakistan: application of STIRPAT model. Environ Sci Pollut Res 26(13):13453–13463

Anwar A, Siddique M, Dogan E, Sharif A (2021) The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: evidence from Method of Moments Quantile Regression. Renew Energy 164:956–967

Asiedu BA, Gyamfi BA, Oteng E (2021) How do trade and economic growth impact environmental degradation? New evidence and policy implications from the ARDL approach. Environ Sci Pollut Res: 1–9

Balsalobre-Lorente D, Bekun FV, Etokakpan MU, Driha OM (2019) A road to enhancements in natural gas use in Iran: a multivariate modelling approach. Res Policy 64:101485

Bekun FV, Alola AA, Sarkodie SA (2019) Toward a sustainable environment: nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Sci Total Environ 657:1023–1029

Bekun, F. V., Gyamfi, B. A., Onifade, S. T., & Agboola, M. O. (2021a). Beyond the environmental Kuznets Curve in E7 economies: accounting for the combined impacts of institutional quality and renewables. Journal of Cleaner Production, 127924.

Bekun FV, Alola AA, Gyamfi BA, Ampomah AB (2021b) The environmental aspects of conventional and clean energy policy in sub-Saharan Africa: is N-shaped hypothesis valid? Environ Sci Pollut Res Int

Bekun FV, Alola AA, Gyamfi BA, Yaw SS (2021c) The relevance of EKC hypothesis in energy intensity real-output trade-off for sustainable environment in EU-27. Environ Sci Pollut Res:1–12

Bera AK, Galvao AF, Montes-Rojas GV, Park SY (2016) Asymmetric Laplace regression: maximum likelihood, maximum entropy and quantile regression. J Econom Methods 5(1):79–101

Bildirici ME, Gökmenoğlu SM (2017) Environmental pollution, hydropower energy consumption and economic growth: evidence from G7 countries. Renew Sust Energ Rev 75:68–85

Breusch TS, and Pagan AR., (1980). The Lagrange multiplier test and its applications to model specification in econometrics. Rev Econ Stud; 47:239e53. https://doi.org/10.2307/2297111

Chen Y, Wang Z, Zhong Z (2019) CO_2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renew Energy 131:208–216

Chokriensukchai K, Tamang R (2010) Thai youths and global warming: media information, awareness, and lifestyle activities. Appl Environ Educ Commun 9(3):198–208

Churchill SA, Inekwe J, Ivanovski K, Smyth R (2018) The environmental Kuznets curve in the OECD: 1870–2014. Energy Econ 75:389–399

Çoban O, Onifade ST, Yussif ARB, Haouas I (2020) Reconsidering trade and investment-led growth hypothesis: new evidence from Nigerian economy. J Int Stud 13(3):98–110

Danish, Baloch MA, Mahmood N, Zhang JW (2019) Effect of natural resources, renewable energy and economic development on CO_2 emissions in BRICS countries. Sci Total Environ 678:632–638. https://doi.org/10.1016/j.scitotenv.2019.05.028

De Silva PNK, Simons SJR, Stevens P (2016) Economic impact analysis of natural gas development and the policy implications. Energy Policy 88:639–651

Demissew Beyene S, Kotosz B (2020) Testing the environmental Kuznets curve hypothesis: an empirical study for East African countries. Int J Environ Stud 77(4):636–654

Destek MA, Sinha A (2020) Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: evidence from Organisation for Economic Co-operation and Development countries. J Clean Prod 242:118537

Dong K, Sun R, Li H, Liao H (2018) Does natural gas consumption mitigate CO_2 emissions: testing the environmental Kuznets curve hypothesis for 14 Asia-Pacific countries. Renew Sust Energ Rev 94: 419–429

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29(4):1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Erdogan S, Okumus I, Guzel AE (2020) Revisiting the environmental Kuznets curve hypothesis in OECD countries: the role of renewable, non-renewable energy, and oil prices. Environ Sci Pollut Res:1–9

Freije AM, Hussain T, Salman EA (2017) Global warming awareness among the University of Bahrain science students. J Assoc Arab Univ Basic Appl Sci 22:9–16

Gyamfi BA, Bein AM, Bekun VF (2020a) Investigating the nexus between hydroelectricity energy, renewable energy, non-renewable energy consumption on output: evidence from E7 countries. Environ Sci Pollut Res 27:25327–25339. https://doi.org/10.1007/s11356-020-08909-8

Gyamfi BA, Bein MA, Ozturk I, Bekun FV (2020b) The moderating role of employment in an environmental Kuznets curve framework revisited in G7 countries. Indonesian Journal of Sustainability Accounting and Management 4(2):241

Gyamfi BA, Ozturk I, Bein MA, Bekun FV (2021a) An investigation into the anthropogenic effect of biomass energy utilization and economic sustainability on environmental degradation in E7 economies. Biofuels Bioprod Biorefin 15(3):840–851

Gyamfi BA, Sarpong SY, Bein MA (2021b) The contribution of the anthropogenic impact of biomass utilization on ecological degradation: revisiting the G7 economies. Environ Sci Pollut Res 28(9): 11016–11029

Gyamfi BA, Adedoyin FF, Bein MA, Bekun FV, Agozie DQ (2021c) The anthropogenic consequences of energy consumption in E7 economies: juxtaposing roles of renewable, coal, nuclear, oil and gas energy: evidence from panel quantile method. J Clean Prod 295:126373

Hanif I, Aziz B, Chaudhry IS (2019) Carbon emissions across the spectrum of renewable and nonrenewable energy use in developing economies of Asia. Renew Energy 143:586–595. https://doi.org/10.1016/j.renene.2019.05.032

Hao LN, Umar M, Khan Z, Ali W (2021) Green growth and low carbon emission in G7 countries: how critical the network of environmental taxes, renewable energy and human capital is? Sci Total Environ 752:141853

Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J Econ 115(1):53–74

Kurniawan R, Managi S (2018) Coal consumption, urbanization, and trade openness linkage in Indonesia. Energy Policy 121:576–583. https://doi.org/10.1016/j.enpol.2018.07.023

Lin B, Omoju OE, Okonkwo JU (2016) Factors influencing renewable electricity consumption in China. Renew Sust Energ Rev 55:687–696

Mahalik MK, Mallick H, Padhan H (2020) Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective. Renew Energy 164:419–432

Meehl GA, Tebaldi C, Walton G, Easterling D, McDaniel L (2009) Relative increase of record high maximum temperatures compared to record low minimum temperatures in the US. Geophys Res Lett 36(23)

Nathaniel SP, Iheonu CO (2019) Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. Sci Total Environ 679:337–345

Nathaniel S, Aguegboh E, Iheonu C, Sharma G, Shah M (2020) Energy consumption, FDI, and urbanization linkage in coastal Mediterranean countries: re-assessing the pollution haven hypothesis. Environ Sci Pollut Res:1–14

Onifade ST, Alola AA, Erdoğan S, Acet H (2021a) Environmental aspect of energy transition and urbanization in the OPEC member states. Environ Sci Pollut Res:1–12

Onifade ST, Çevik S, Erdoğan S, Asongu S, Bekun FV (2020) An empirical retrospect of the impacts of government expenditures on economic growth: new evidence from the Nigerian economy. J Econ Struct 9(1):6

Onifade ST, Erdoğan S, Alagöz M, Bekun FV (2021b) Renewables as a pathway to environmental sustainability targets in the era of trade liberalization: empirical evidence from Turkey and the Caspian countries. Environ Sci Pollut Res:1–12

Ozturk I, Al-Mulali U (2015) Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. Ecol Indic 57:324–330

Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, ... & Van Ypserle JP (2014) Climate change 2014: synthesis report. Contribution of Working Groups I. II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), 151.

Pata UK (2020) Renewable and non-renewable energy consumption, economic complexity, CO 2 emissions, and ecological footprint in the USA: testing the EKC hypothesis with a structural break. Environ Sci Pollut Res:1–16

Pata UK, Yilanci V (2020) Financial development, globalization and ecological footprint in G7: further evidence from threshold cointegration and fractional frequency causality tests. Environ Ecol Stat 27(4):803–825

Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Econ 22(2):265–312

Pesaran MH (2015) Testing weak cross-sectional dependence in large panels. Aust Econ Rev 34(6–10):1089–1117

Rahman ZU, Chongbo W, Ahmad M (2019) An (a) symmetric analysis of the pollution haven hypothesis in the context of Pakistan: a non-linear approach. Carbon Management 10(3):227–239. https://doi.org/10.1080/17583004.2019.1577179

Salman M, Long X, Dauda L, Mensah CN, Muhammad S (2019) Different impacts of export and import on carbon emissions across 7 ASEAN countries: a panel quantile regression approach. Sci Total Environ 686:1019–1029

Shahbaz M, Shahzad SJH, Mahalik MK, Hammoudeh S (2018) Does globalisation worsen environmental quality in developed economies? Environ Model Assess 23(2):141–156

Sharif A, Baris-Tuzemen O, Uzuner G, Ozturk I, Sinha A (2020) Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: evidence from Quantile ARDL approach. Sustain Cities Soc 102138

Sharif A, Raza SA, Ozturk I, Afshan S (2019) The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations. Renew Energy 133:685–691

Sherwood B, Wang L (2016) Partially linear additive quantile regression in ultra-high dimension. Ann Stat 44(1):288–317

Solarin SA, Al-Mulali U (2018) Influence of foreign direct investment on indicators of environmental degradation. Environ Sci Pollut Res 25(25):24845–24859

Solarin SA, Al-Mulali U, Musah I, Ozturk I (2017) Investigating the pollution haven hypothesis in Ghana: an empirical investigation. Energy 124:706–719

Taiwo S, Alagöz M, Erdoğan S (2020) Inflation, oil revenue, and monetary policy mix in an oil-dependent economy: empirical insights from the case of Nigeria. Int J Bus 7(2):96–109

Thaker J, Smith N, Leiserowitz A (2020) Global warming risk perceptions in India. Risk Anal 40(12):2481–2497

Trenberth KE (2012) Framing the way to relate climate extremes to climate change. Clim Chang 115(2):283–290

Trenberth KE (2011) Changes in precipitation with climate change. Clim Res 47:123–138. https://doi.org/10.3354/cr00953

Ulucak R, Ozcan B (2020) Relationship between energy consumption and environmental sustainability in OECD countries: the role of natural resources rents. Res Policy 69:101803

UNEP (2018) The emissions gap report 2018. United Nations Environment Programme, Nairobi

Westerlund J (2007) Testing for error correction in panel data. Oxf Bull Econ Stat 69(6):709–748

Yilanci V, Ozgur O (2019) Testing the environmental Kuznets curve for G7 countries: evidence from a bootstrap panel causality test in rolling windows. Environ Sci Pollut Res 26(24):24795–24805

Yilmaz V, Can Y (2020) Impact of knowledge, concern and awareness about global warming and global climatic change on environmental behavior. Environ Dev Sustain 22(7):6245–6260

Zhu H, Duan L, Guo Y, Yu K (2016) The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: evidence from panel quantile regression. Econ Model 58:237–248