Environmental Science and Pollution Research (2021) 28:37459–37470
https://doi.org/10.1007/s11356-021-13380-0

RESEARCH ARTICLE

Roadmap for climate alliance economies to vision 2030: retrospect and lessons

Festus Fatai Adedoyin[1] · Festus Victor Bekun[2] · Andrew Adewale Alola[2]

Received: 22 January 2021 / Accepted: 8 March 2021 / Published online: 13 March 2021

Abstract

The United Nations Climate Conference 25, held in December 2019, reached a significant agreement against implementing the Paris agreement come 2020. Bound by the contract, 189 countries who are party to the deal agreed to constrain worldwide temperature to ascend to 1.5° Celsius. To this end, the present study attempts to investigate the readiness of selected countries in the European Union to implement the agreement, which will better the quality of the global environment. In line with this, this study appraises the connection between economic growth, renewable and non-renewable energy consumption, on emissions in 11 countries in the European Union from 1990 to 2016. The study utilises the Pooled Mean Group-Auto Regressive Distributed Lag (PMG-ARDL) model estimator and Dumitrescu and Hurlin Panel Causality analysis to analyse the long-run and short-run impact and direction of causality among these factors, respectively. The long-run study's empirical results show a U-shaped Environmental Kuznets Curve (EKC) and a negative connection between renewable energy use and emissions in the EU-11 countries. In the short-run, non-renewable energy use worsens CO_2 emissions while renewable energy use leads to a fall in emissions. Similarly, causality tests show a feedback mechanism between emissions and renewable energy use and between non-renewable energy and renewable use. Also, there is unidirectional causality from income to CO_2 emissions, non-renewable energy use to CO_2 emissions. The investigation recommends an expanded proportion of renewable energy sources in the EU countries' energy mix to cut down on emissions.

Keywords CO_2 emissions · Renewable energy · Non-renewable energy · Economic growth · Environment

Introduction

Energy has become the bedrock in the global economy to promote renewable energy development of countries. The link between energy demand and economic enhancement has garnered financial experts and politicians' attention in environmental and energy economics literature. The general submission is based on the premise that energy demand is a major driver of economic growth. However, the demand for energy resources is mainly linked to two sources: non-renewable and renewable energy. Instances of non-renewable energy source consist of petroleum product, coal, nuclear power etc. in which there is no possibility of recovery after consumption. On the other hand, renewable energy source assets are unlimited in supply and can also be regenerated, unlike its counterpart; for instance, solar, biomass, wind energy and hydroelectric are notable examples of renewable energy sources.

Meanwhile, non-renewable energy sources have recorded a larger rate of consumption globally. Specifically, fossil fuel energy has been recognised as the most used component worldwide (Sebri and Ben-Salha 2014a, b). Akin to this, non-renewable energy resources have also been recognised as the major determinant of worldwide climate change and

Responsible editor: Ilhan Ozturk

✉ Festus Victor Bekun
fbekun@gelisim.edu.tr

Festus Fatai Adedoyin
fadedoyin@bournemouth.ac.uk

Andrew Adewale Alola
aadewale@gelisim.edu.tr

1 Department of Computing and Informatics, Bournemouth University, Poole, UK

2 Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey

warming. The environmental concerns evolving around utilising non-renewable energy have made it necessary to look for alternative energy sources for renewable energy economic growth. The rationale behind the policy is to peg the use of perishable energy to control its damaging environmental quality effects. In literature, the policy attention has been diverted to the adoption of renewable energy as a viable alternative for non-renewable energy due to the friendly nature of the former to the long-term interests of humans (see Aydin 2019; Destek and Aslan 2017; Hanif et al. 2019a, b; Salim et al. 2014; Troster et al. 2018).

The International Energy Outlook report in 2016 oversees that the alarming rate of CO_2 emissions as a result of fossil fuel energy resources cannot be delinked from the climate change experienced in the world. The report's estimation states that CO_2 emissions as necessitated by fossil fuel energy resources would increase up to around 35.6 billion metric tons as of 2020 and may increase up to 43.2 billion metric tons in 2040. The basis of the argument as entailed in the report is that fossil fuel energy resources, as an economic growth engine, are adversely affecting the climatic condition. The energy-induced climate change has consequential effects on the diversity of life, such as rising sea levels, warming of oceans, endangering fresh water supplies and crops by droughts and creating a barrier for the means of sustenance of the growing world population. These call for a well-structured renewable energy economic model that can be employed to mitigate the adverse effects.

To mitigate the effect of energy exploitation on climate, United Nations Framework Convention on Climate Change (UNFCCC) held the Parties Conference, which is also regarded as COP25, in December 2019 in Madrid, Spain. The conference was a prelude to the Paris Agreement of 2015. The Paris Agreement was held with the core objective of creating a legal framework through which climate change would be mitigated by keeping the global temperature limited to 1.50°C and ensuring countries' resilience to climate impacts. So, COP25 was set out to provide guidelines for administering the Paris Agreement and help countries meet their targets of curbing greenhouse emissions' effects on the climate. The Climate alliance was engineered to bring together nations and other stakeholders to upscale action by 2020 to achieve zero-net carbon emission by 2050. The progress of COP25 as measured by the United Nation Development programme shows that over 70 countries have given the pledge to be neutral in terms of carbon emission by 2050 (UNDP 2019). Therefore, all countries need to follow the laid down guidelines of the COP25 as it embraces zero-net carbon emissions by 2050 and thereby put energy-induced environment concerns under control. European Union (EU11) is no exception. It is one of the major contributors to global discharge; the union has put measures to decouple carbon dioxide outflows from economic growth to militate against global warming and weather change.

Interestingly, the EU announced its targets for 2030, including reducing GHG emissions by 40%, 27% target for renewable energy and efficient energy improvement to a minimum of 27%. The major difference between the 2020 targets and 2030 targets is that no agreement was reached for the former on the allocation of responsibility based on county-by-country for meeting the targets. Consequently, the Paris accord conference that was adopted by 195 nations in December 2015, recorded the most universally accepted global climate deal. The policy maps out international strategic approaches to set the world's pathway in a bid to neutralise climate change by setting global warming to below 20°C. The EU opened the floor for other economies as the first economy to tender its planned input to the newly agreed target and pledging at least 40% internal reduction of GHG emissions by 2030. However, the feasibility of achieving the best of the medium-term targets of carbon emissions has been lacklustre because of inadequate analysis. As a frontline continent of global climate change monitoring having aims set for 2020 and 2030, the continent is still fulfilling the alliances' pledge.

Thus, this current study will produce a critical analysis of the channels through which EU-11 can learn through the framework of the climate alliance's roadmap to vision 2030. This study differs from other studies contextually because of the uniqueness of the selected countries. Previous studies have ignored these selected countries. Thus, there is little or no empirical evidence concerning the nations. Moreover, the study contributes to existing literature methodologically via the set of variables used in the study, unlike the previous studies' variable combination. The next section presents a rich discussion on the arguments in the literature related to the consumption of energy from renewable and non-renewable sources, economic growth, and their linkage with pollutant emissions. In the "Data and methods" section, we present the data used for the empirical exercise, while the main findings of this study are discussed in the "Results and Discussions" section with comparison and contrast with previous research. The "Conclusion and Policy Recommendations" section concludes the study with vital policy implications for the EU.

Literature review

Pollutant emissions

In recent times, carbon emissions (CO_2) have gained attention across the globe because of their contribution to global warming and the depletion of the environment (Nathaniel et al. 2021). It has become a threat to sustainable development (Nathaniel and Iheonu 2019). Humans' economic and non-economic activities are the major booster of global emissions (Nathaniel et al. 2021). Energy consumption is tied to economic activities. Most economic activities use renewable and non-renewable energy (Paramati et al. 2017). As economic activities increase, so does energy consumption. One of the widely used energy is fossil fuel. It is a major cause of air pollution across the globe. According to Paramati et al. (2017), two fundamental problems encountered by economies because of continuous consumption of fossil fuel-based energy are depletion of non-renewable energy and carbon dioxide emission (CO_2). Due to the release of pollutant emissions in the form of greenhouse gasses, economies of the world are beginning to move from the continuous consumption of non-renewable energy, e.g., fossil fuel, to renewable energy such as solar, wind etc. (Sinha et al. 2017; Ahmed et al. 2021). Moreover, the pollution that comes from CO_2 negatively affects the health of the people and results in death in some cases. As a result of this, economies are shifting ground from non-renewable energy to renewable energy considered clean, low pollutant emission, and less destructive to the environment (Zhang et al. 2013).

Pollutant emissions and renewable and non-renewable energy consumption

The discourse on energy consumption-economic growth-emissions nexus has attracted considerable volume of attention in the last decade with enormous empirical research on the linkage among power resource utilisation (renewable energy and perishable), income per capita and environmental quality (Adedoyin et al. 2020a, b, c, e; Adedoyin and Zakari 2020; Etokakpan et al. 2020; Kirikkaleli et al. 2020; Udi et al. 2020). The majority of these studies considered carbon emission as the most reliable and sophisticated indicator of environmental degradation. To mention but a few, in a more recent study, Nathaniel and Adeleye (2021) examine the factors that impede environmental sustainability using CO_2 emissions and ecological footprint in 44 selected African countries from 1990 to 2016. Using both static and dynamic econometric techniques, the findings show that energy use worsens the environment and urbanisation. Nathaniel and Iheonu (2019) investigated the role of renewable and non-renewable in reducing CO_2 emissions in 19 selected African countries from 1990 to 2014. Employing the Augmented Mean Group estimation technique, results reveal that while renewable energy decreases CO_2 emissions insignificantly, non-renewable energy boosts CO_2 emissions in Africa.

Zhang et al. (2013) investigated the nexus between power exhaustion, GDP per capita and emissions in the Chinese economy over time from 1978 to 2007, and it is discovered in the study that the growth-induced emissions are owing to the non-renewable energy utilisation sources and thereby gave a suggestion of energy mix policy as a way to put the environmental degradation under considerable control. Shafiei and Salim (2014) searched the factors that determine carbon emissions in OECD countries from 1980 to 2011 within the two primary energy sources. They discovered that non-renewable energy consumption contributes positively to environmental degradation through carbon emissions while renewable energy affects it negatively. In similar studies, Sinha and Shahbaz (2018) attempted to validate the existence of EKC for CO_2 emission in India between 1971 and 2015. Based on the Autoregressive Distributed Lag model, the study found a negative and significant relationship between renewable energy and CO_2 emission. Sebri and Ben-Salha (2014b) lay more emphasis on the duty of clean energy sources in paving the way for a rise in the economic boost and lowering of CO_2 discharge in BRICS nations based on the results obtained from the ARDL Bounds Testing Approach and Vector Error Correction Model (VECM) for the annual duration from 1971 to 2010.

Furthermore, the Granger causality approach adopted by Wang et al. (2016) in the Chinese economy covering the time interval from 1990 to 2012 showed that consumption of unclean energy resources Granger causes carbon emissions in the economy. A study conducted by Bilgili et al. (2016) attempted to verify the EKC hypothesis within the context of renewable energy utilisation and environmental quality for 17 OECD nations over the period from 1977 to 2010. They concluded that the EKC hypothesis exists and carbon emissions are reduced significantly through renewable energy exploration. Sinha and Shahbaz (2018) obtained a similar result, although in a different context and methodological adaptation. Another study on 25 OECD nations from 1980 to 2010, Ben Jebli et al. (2016) affirmed the rationality of EKC theories in and the results obtained from the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) also revealed that increase and reduction of carbon emissions can be attributed to non-renewable and renewable power utilisation, respectively. The output obtained from the study conducted by Dogan and Seker (2016a, b) revealed that the enabling factor of environmental degradation in EU countries is the unrenewable energy use while the adoption of renewable energy reduces it. Utilising cointegration and Granger causality methods, Boontome et al. (2017) validated the existence of input speculation between non-renewable energy source utilisation and discharges in Thailand over the period from 1971 to 2013. They also recommended adopting clean energy resources to lower the adverse consequence of non-renewable energy on the environment. Zafar et al. (2019) categorise energy into renewable and non-renewable energy and investigate their impact on economic growth between 1990 and 2015 in the Asia Pacific Economic cooperation countries. Using the

FMOLS and DOLS, the study results reveal that energy consumption can facilitate economic growth, renewable energy consumption can cause economic growth, and economic growth can cause non-renewable energy. The study also shows that renewable energy boost economic growth in each country.

To further strengthen the discourse, Zaman and el Moemen (2017) provided a detailed investigation of the linkage between GDP per capita, power consumption and CO_2 emission under the condition of six major hypotheses on 90 countries separated by the level of income (low and average inflow countries and high inflow nations) within the period from 1975 to 2015. The panel analysis results affirmed the EKC hypothesis and vitality incited outflows over the regions suggesting drastic measures to counter the environmental problems. Ito (2017) used a panel dataset from 2002 to 2011 for 42 developing economies to investigate the linkage between emissions, renewable energy and non-renewable energy consumption and GDP boost and concluded that non-renewable power utilisation adversely affects the economic increase as it further deepens the environmental pollution experienced in the economies whereas show opposite result for renewable energy. The study of Cherni and Essaber Jouini (2017) recognised renewable energy as a viable replacement for conventional non-renewable energy in Tunisia after discovering no form of relationship between the former and carbon emissions.

Additionally, Inglesi-Lotz and Dogan (2018) carried out an empirical study on 10 Sub-Saharan African nations with electricity generation from 1980 to 2011 indicating that environmental pollution is mainly caused by non-renewable energy while the opposite holds for renewable energy. Chen et al. (2019a, b) carried out a regional analysis of the effects of GDP growth, renewable energy and non-renewable energy use on carbon emission in China from 1955 to 2012. The study results revealed that perishable power utilisation donates to carbon emission while renewable energy reduces it. Paramati et al. (2017) examine the role of renewable energy consumption and CO_2 emissions in fast-growing economies of the world from 1990 to 2012 using different Panel estimators. Renewable energy is observed to boost economic growth but decreases CO_2 emission. Bekun et al. (2019) in a recent study of selected 16 EU countries, applied Panel Pooled Mean Group-Autoregressive Autoregressive distributive lag model (PMG-ARDL) to examine the associational nexus between renewable energy utilisation sources and non-renewable power consumption sources, GDP per capita growth and carbon emissions. The study discovered that carbon emissions are expunged by renewable energy consumption while non-renewable energy utilisation and GDP per capita growth contribute to the rise of carbon emissions. Using a panel dataset of 74 nations over the period from 1990 to 2015, Sharif et al. (2019) discovered the positive effect of clean energy sources on the environmental quality while the consumption of non-renewable energy resources augments ecological hazards. Maji and Sulaiman (2019) revealed that the adoption of renewable energy as an alternative to unclean energy sources in 15 West African countries causes a retraction of the economies' economic growth.

Pollutant emissions and economic growth

The nexus between pollutant emissions and GDP per capita has been extensively examined in the environmental economics literature. However, the relationship has been widely addressed in the literature using different econometrics analyses such as causality tests, cointegration, ARDL method and the popular Environmental Kuznets Curve (EKC) postulation. Shahbaz and Sinha (2019) surveyed the EKC estimation of CO_2 emissions from 1991 to 2017 to understand the present level of knowledge and possible gap. The survey literature on EKC estimation of CO_2 emissions is grouped into two based on cross-country analysis and single-country analysis. Findings from the survey show that the empirical evidence on the hypothesised inverted-U relationship between growth and CO_2 emission is mixed and inconclusive due to certain factors that include the difference in methods employed, context, the scope of the study, and variables. The study further suggests that future studies should refine the data set and use a set of new variables. Sinha et al. (2017) employed the Generalised Method of Moment to examine the EKC for CO_2 emission in N-11 countries between 1994 to 2014 by adding biomass to the popularly used renewable and non-renewable energy consumption. The renewable energy generation process is observed to boost economic growth in the N-11 countries and found an N-shaped relationship between economic growth and environmental degradation in the sub-panel regions.

The results emerging from empirical studies on growth-induced pollutant emissions have revealed that increased productivity contributes to pollutant emissions to a particular extent (Hanif et al. 2019a, b). The rationale behind general submission on growth-induced carbon emission in the literature can be found from the reliance of most countries on non-renewable energy sources. However, the association and the track of the causality between GDP growth and pollutant emissions are still seriously debated in the literature. The study of Al-mulali (2011) on MENA countries over the period from 1980 to 2009 through the application of Granger Causality tests revealed the existence of a feedback hypothesis between GDP growth and carbon emissions. Similarly, on 14 MENA nations over time from 1990 to 2011, Omri (2013) re-examined the causal linkage between power utilisation, GDP increase and carbon discharge and discovered feedback effects between GDP boost and carbon emissions.

Furthermore, Du et al. (2012) examined the provincial investigation of the determinants of carbon outflows in China and found the effects of energy consumption insignificant. The study further found that the significant determinants of carbon outflows in China provinces are economic development, technology advancement, and volatile industry structure. Cowan et al. (2014) discovered mixed results on the linkage between GDP increase and carbon discharge in BRICS. The results indicated a one-way causal linkage moving from GDP boost to carbon emissions for South Africa and the opposite direction for Brazil confirmed feedback hypothesis for the Russian economy and no causality for China and India. The empirical observation of India, Indonesia, China, and Brazil by Alam et al. (2016) discovered the positive association between real income and carbon emission. Adams et al. (2016) carried out an empirical investigation of the direction of effects between consumption of energy resources and GDP growth within the context of the democratic system of government in Sub-Saharan African countries and validated the feedback effects between energy resources and real income. Abdouli and Hammami (2017) investigated the focus of causality linkage between the quality of the environment, foreign direct investment and GDP growth within the time frame from 1990 to2012 and confirmed the feedback effects between GDP growth and environmental pollution. Tamba (2017) discovered through the application of cointegration and Granger causality tests, strong evidence for feedback hypothesis between GDP growth and carbon emission for Cameroon for the duration from 1971 to 2013. The results of Dumitrescu-Hurlin non-causality approach adopted by Dogan and Inglesi-Lotz (2017) on 15 EU countries over the period from 1980 to 2012 showed a one-way directional linkage moving from real GDP to carbon emission.

Also, Antonakakis et al. (2017) investigated output–energy-environment nexus in 106 countries differentiated by the levels of income over the period from 1971 to 2011. They discovered that a continued process of productive activities gave rise to environmental concerns. Mirza and Kanwal (2017) applied the ARDL approach to investigate the causality relationship among power exhaustion sources, GDP increase and carbon discharge and validated the feedback hypothesis for the increase and carbon discharge nexus. The results of the panel vector autoregression (PVAR) and system-generalised method of moment (System-GMM) employed by Acheampong (2018) on a sample of 116 countries from different regions in the world showed that GDP growth has no causal linkage with carbon emission both at the regional and global levels. Gorus and Aslan (2019) on MENA countries examined the impacts of different economic variables from 1980 to 2013 and specifically discovered that GDP growth contributes more to the environmental pollution in most MENA counties. Shahbaz et al. (2019) found a long-run validity of the EKC hypothesis in Vietnam over the sample period from 1974 to 2016. Uzar and Eyuboglu (2019) found an astonishing result in Turkey on the association between inequality in income distribution and environmental quality. They discovered that unfairness in the distribution of income exerts an adverse effect on the environment's quality. Munir et al. (2020) revisited the nexus among carbon emission, power consumption and GDP increase of ASEAN-5 nations over the period from 1980 to 2016. They discovered a one-way directional alliance moving from GDP per capita increase to carbon emission (Table 1).

Data and methods

Data and variables

The information utilised in this research is collected from the World Bank Development Indicators. For pollutant emission, we use Carbon dioxide emissions as a proxy, Income is represented by real Gross domestic product (constant $2010), renewable energy by Renewable energy utilisation (% of total final energy) and non-renewable energy consumption by non-renewable consumption (kg of oil equivalent).

Model and methods

Following the empirical modelling of Nathaniel and Iheonu (2019), to assess the effect of GDP, renewable energy source and non-renewable energy source utilisation on CO_2 emissions and to investigate the resulting implications for achieving the C0P25 targets in the EU 11, the following model equation is proposed:

$$LNCO2 = f(LNGDP, LNREC, LNNREC) \quad (1)$$

$$LC02 = \alpha_0 + \beta_1 LNGDP_{it} + \beta_2 LNREC_{it} + \beta_3 LNNREC_{it} + \varepsilon_{it} \quad (2)$$

The equation variables have been log-transformed to ensure that a consistent difference over all the arrangement is obtained. Where $LNCO_2$, *LNREC, LNNREC, LNGDP* are logarithmic modifications of all factors and ε_{it} , α and β's represents the stochastic, intercept, and partial slope coefficients, respectively. The econometric technique utilised in the study is the Pooled Mean Group-Autoregressive Distributed Lag (PMGARDL) estimator. This technique can analyse both the short and long-term estimates using the Pesaran et al. (1999) procedure. This procedure will require

Table 1 Description of data under review

Series name	Symbol	Source
Pollutant emission (Kt)	CO_2	WDI
Real gross domestic product (constant $2010)	GDP	WDI
Renewable energy consumption (% of total final energy)	REC	WDI
Non-renewable energy consumption (kg of oil equivalent)	NREC	WDI

Source: Authors compilation, where WDI represents world development indictor's database (http://data.worldbank.org/) accessed date May 2020

an Autoregressive Distributed Lag (ARDL: p, q) structure that includes lags of $C0_2$ emissions and other regressors, given by:

$$LC02_{it} = \beta_i + \sum_{j=0}^{p} \delta_{ij} LCO2\ Z_{it-j} + \sum_{j=1}^{q} \varphi\delta_{i,j} Z_{it-j} + \varepsilon_{it} \qquad (3)$$

where, Z_{it} = ($LNREC_{it}$, $LNNREC_{it}$, $LNGDP_{it}$), which is the vector of explanatory factors. β_i represents the country-level fixed effects, δ_{ij} stands for the slope of the lagged emissions factor and $\varphi_{i,\ j}$ stands for the slope of lagged explanatory factors. The method used in this study involves both the preliminary test and econometric technique. The initial test starts with a summary of descriptive statistics. This presents the characteristics of the data series in the model in terms of the mean, standard deviation, minimum and maximum etc. The correlation analysis is performed to examine the potential relationship between the explained variable and the explanatory variable. This helps to determine the relationship between the explanatory variables to avoid the problem of multi-collinearity. To examine the presence of mean reversion and constant variance, we adopt the ADF-Fisher and the Im-Pesaran-shin unit root test while the Johansen Fisher co-integration tests and Pedroni Co-integration test are used to test the presence of long-run equilibrium relationship. The stationarity examination of the series is necessary to ensure that the series examines the properties required to avoid a spurious regression. To estimate the specified model and understand how renewable and non-renewable energy affect CO_2 emissions, we adopt the pooled mean group with dynamic autoregressive distributed Lag. The advantage of the ARDL cointegration estimator over the popular panel data models is notable. Firstly, it can account for endogeneity issues in econometric models while pleasing both short-run and since quite a while ago run parameters. Besides, the ARDL cointegration permits the incorporation of factors in a blended request of coordination for example I(0) or/and I(1), however not I(2) specifically, which features other estimators do not offer. Pesaran et al. (1999) present that the Pool Mean Group (PMG) estimator is not only just dependable but also vigorous and sufficiently able to slack requests and anomalies. Also, we employ the Dumitrescu and Hurlin Panel Causality test to examine the direction of causality among the model variables. The Dumistrescu and Hurling test helps determine if the independent variables can predict the dependent variable's future values.

Results and discussions

Pre-estimation diagnostics: descriptive statistics and correlation

Table 2 presents the outline insights and correlation matrix for the study variables. An examination of the data shows that LNGDP has the highest average value of 715.883, which falls within the range of 519.50 and 838.80. LNNREC and LNREC follow this with an average value of 8.43 and 8.24 within the scope of 7.43 and 9.81, 2.90 and 10.57. $LNCO_2$ recorded the lowest mean value of 0.60 which falls within the range −1.14 and 1.19. The standard deviation shows the variation of the series from their mean. It shows that except

Table 2 Summary and correlation analysis

	$LNCO_2$	LNGDP	LNNREC	LNREC
Mean	0.60379	715.883	8.42613	8.2389
Median	0.84226	716.34	8.34018	8.55624
Maximum	1.19049	838.797	9.80798	10.5691
Minimum	−1.1443	519.495	7.42712	2.90142
Std. dev.	0.48027	87.6849	0.48247	1.58961
Skewness	−1.6815	−0.5826	0.58554	−1.5065
Kurtosis	5.66298	2.49795	3.40131	5.20241
Jarque-Bera	227.714	19.922	18.9646	172.363
Probability	0	4.7E-05	7.6E-05	0
Sum	179.324	212617	2502.56	2446.95
Sum sq. dev.	68.274	2275838	68.903	747.952
Observations	297	297	297	297
	Correlation analysis			
$LNCO_2$	1			
LNGDP	0.42296	1		
LNNREC	−0.6307	−0.6342	1	
LNREC	−0.3015	0.57383	−0.3494	1

LNGDP, all the series have small variability. The series' distribution further reveals that the series is not normally distributed since the *p*-value of the Jarque-Bera statistics of all the series is less than 0.05. This further implies that the stationarity properties of the series need to be examined.

The correlation matrix shows the potential signs between LNCO and the other series. According to the correlation matrix, there is a positive direct connection between LNGDP and LNC02, while there is a negative direct connection between LNNREC, LNREC and LCO_2. The correlation coefficients between the series are small. This indicates that the series is moderately correlated and removes the possible problem of multicollinearity.

Stationarity and cointegration

To proceed with the model's estimation, it is vital to test for non-stationarity in the study variables. For this purpose, the ADF-Fisher and Im-Pesaran-Shin non-stationarity tests have been utilised and results are shown in Table 3. Accordingly, all factors are fixed from the start distinction as appeared by the outcomes. At level, none of the variables is stationary in both the ADF-Fisher and Im-Pesaran-Shin tests. However, after taking the first difference of the series, they are stationary at a 1% significant level. This suggests that the series exhibit mean reversion and constant variance which are properties needed to avoid a spurious analysis. Table 4 presents cointegration test results using two methods namely, the Pedroni cointegration test and the Johansen Fisher cointegration tests. Following the significant *p*-values from both tests, we reject the null hypothesis that the factors are not cointegrated. Hence, we conclude that the model variables are cointegrated.

Estimation: pooled mean group with dynamic autoregressive distributed lag

Table 5 displays the outcomes for the estimation of $C0_2$ emissions using the PMG estimator. Both the long- and short-run

Table 3 Non-stationarity analysis

	ADF-Fisher		Im, Pesaran Shin	
	Level	Δ	Level	Δ
LnGDP	17.9602	65.6738***	0.7538	−5.18900***
LnREC	21.3568	103.592***	0.4957	−8.1725***
lnNREC	8.78221	92.3862***	2.4277	−7.4057***
lnCO2	27.9233	97.2288***	0.7385	−6.26913***

Note: ***, **, * represents 1, 5 and 10% statistical rejection level, respectively, and Δ symbolises the first difference. The model fitted with intercept and trend

Table 4 Cointegration analysis

Alternative hypothesis: common AR coefs. (within-dimension)	Statistic	Prob.	Weighted Statistic	Prob.	Alternative hypothesis: individual AR coefs. (between-dimension)	Statistic	Prob.
Panel v-Statistic	1.423419	0.0773	0.214441	0.4151	Group rho-Statistic	-0.693066	0.2441
Panel rho-Statistic	-1.044818	0.1481	-1.794446	0.0364	Group PP-Statistic	-6.487003	0.0000
Panel PP-Statistic	-3.722689	0.0001	-5.712020	0.0000	Group ADF-Statistic	-1.900708	0.0287
Panel ADF-Statistic	-2.399180	0.0082	-2.568725	0.0051			

Johansen Fisher cointegration test

Hypothesised No. of CE(s)	Fisher Stat. (from trace test)	Prob.	Fisher Stat. (from max-eigen test)	Prob.
r≤0	196.9***	0.0000	132.3	0.0000
r≤1	89.89***	0.0000	61.91	0.0000
r≤2	[illegible]***	0.0020	34.36	0.0451
r≤3	27.76	[illegible]	23.34	0.3829
r≤4	28.19	[illegible]	28.19	0.1696

Note: ***, **,* represent 1, 5 and 10% statistical rejections, respectively

Table 5 Pooled mean group with dynamic autoregressive distributed lag

Model: lnCO2 = f (lnGDP, lnGDP2, lnREC, lnNREC)

Variable	Coefficient	SE	T-Stat	*P*-value
Long-run equation				
LNGDP	−0.08439***	0.027921	−3.0225	0.0028
LNGDP2	5.57E-05***	1.88E-05	2.957612	0.0034
LNEU	−0.01559	0.05936	−0.26267	0.7931
LNRE	−0.09626***	0.02028	−4.74657	0.0000
Short-run equation				
ECT	−0.27686***	0.097905	−2.82782	0.0051
D(LNGDP)	0.067766	0.126889	0.534061	0.5938
D(LNGDP2)	−4.63E-05	8.46E-05	−0.54724	0.5848
D(LNEU)	0.347381***	0.12212	2.84458	0.0049
D(LNRE)	−0.18811**	0.109986	−1.71029	0.0886
Constant	9.224993***	3.277288	2.814826	0.0053

Note number of observations 297, information criterion-Akaike information criterion (AIC), maximum lag 1 as outlined by AIC. Note: ***. **, * represent 1, 5 and 10% statistical rejections, respectively

models are significant and consistent with previous findings. Accordingly, long-run results reveal a negative coefficient for LNGDP and a positive coefficient for LNGDP2 (at a 1% level of significance), which confirms a U-shaped Environmental Kuznets Curve in the EU-11 countries. This result aligns with Lipford and Yandle (2010) findings, who found a U-shaped EKC for the G8 and other five countries, and Musolesi et al. (2010), who found a U-shaped EKC for some non-OECD countries. This suggests that as income increases in the E11 countries, emissions will fall for a short while and then begin to rise in the future. However, the fall and rise in emissions due to an increase in income are inelastic, as emissions fall by 0.084% in the short run and rise by 0.0000557% in the long run.

The correlation between non-renewable energy source and emissions is negative but unimportant, although renewable energy utilization reduces emissions by an average of 0.096% (at a 1% level of importance). The results are consistent with that of Dong et al. (2017) and Pata (2018). They suggest that, as more renewable energy is used, carbon emissions begin to fall, which means that the environment's quality will continue to improve in the E11 countries. This result is as expected because most sources of renewable energy do not produce carbon emissions. As such, higher consumption of renewable energy in the EU will continue to lower emission levels in the region.

In the short run, the mistake revision term is essential and negative, which infers that there is, since a long time ago, a run relationship among the factors in the model. The coefficients for LGDP and LGDP2 are positive, negative, but insignificant, respectively. This entails that a rise in income will be deficient of a vital influence on discharge in the short run. However, results reveal a positive and noteworthy connection between non-renewable energy use and emissions at a 1% level of importance. Specifically, a 1% growth in non-renewable energy use will lead to the growth of emissions by 0.347381% in the short run. This result agrees with Belaid and Youssef (2017) and Chen et al. (2019a, b) findings. This outcome signifies that an increase in the exhaustion of non-renewable forms of power will increase emissions in the E11 countries in the short-run period, thus causing damage to the natural environment. As expected, renewable energy source negatively affects outflows in the short run at a 5% level of significance, which signifies that increased consumption of renewable forms of energy will reduce the levels of emissions in the environment, thereby improving the environment's health in the E11 countries.

Dumitrescu and Hurlin Panel Causality analysis

Table 6 shows the outcome of the panel causality investigation. As can be seen, there is bidirectional causality between renewable energy and CO_2 emissions, renewable energy use and non-renewable energy use. This signifies that emissions are a causative agent to renewable energy use and vice versa. Similarly, non-renewable energy use is a causative agent to renewable energy and vice versa. Comparing this result to previous studies, we find that the bidirectional causality between practical power source agrees with the investigations of Apergis and Payne (2014) for 7 central American countries while the bidirectional causality between

Table 6 Dumitrescu and Hurlin Panel Causality analysis

Null hypothesis	W-Stat.	Zbar-Stat.	*p*-value
LNGDP ≠ LNCO2	5.61514***	4.52926	6.E-06
LNCO2 ≠ LNGDP	3.12333	1.20291	0.2290
LNEU ≠ LNCO2	3.42660*	1.60774	0.1079
LNCO2 ≠ LNEU	2.98938	1.02409	0.3058
LNRE ≠ LNCO2	4.67288***	3.27142	0.0011
LNCO2 ≠ LNRE	3.58322*	1.81681	0.0692
LNEU ≠ LNGDP	1.09517	-1.50452	0.1324
LNGDP ≠ LNEU	5.15374***	3.91334	9.E-05
LNRE ≠ LNGDP	1.85580	-0.48915	0.6247
LNGDP ≠ LNRE	5.42895***	4.28072	2.E-05
LNRE ≠ LNEU	7.85114***	7.51413	6.E-14
LNEU ≠ LNRE	3.90760**	2.24983	0.0245

Source: Authors computation. Note: ***. **, * depict 0.01, 0.05 and 0.10 rejection levels, respectively renewable and non-renewable energy is similar to the findings of Jebli et al. (2016) for OECD countries. This, by implication for policy analysis, means that CO_2 emission can predict movement in energy consumption (both renewable and non-renewable), and energy consumption can also predict changes in the direction of CO_2 emission in E11 countries. In other words, as renewable energy consumption is increasing, CO_2 will be affected in the future, and the rising effect on CO_2 will necessitate more consumption of renewable energy.

However, there is unidirectional causality moving from pay to $C0_2$ outflows, from non-renewable energy source use to CO_2 emissions, from income to non-renewable energy source use and from income to renewable energy source use. These results illustrate that income directly affects carbon discharge, renewable energy use and non-renewable power use in the E11 countries. Sadorsky (2009) discovered a unidirectional causality from income to renewable energy and Dogan and Seker (2016b) realised a unidirectional causality from income to emissions for the G7 countries and the European Union, respectively. Also, Shafiei and Salim (2014) found a one-way causality from non-renewable energy to carbon discharge.

Another implication of the results is that the impact of income on emissions is in two ways. First, income directly impacts emissions, and it has an indirect effect on emissions traced through its impact on renewable and non-renewable energy use.

Conclusion and policy recommendations

This study focuses on the European Union's readiness to implement the Paris Agreement, which reached important deliberations at the COP25 in December 2019. We estimate an economic model to break down the connection between economic growth, renewable energy source and exhaustible energy on pollutant emissions in 11 countries in the European Union from 1990 to 2016. We use the PMG-ARDL estimator, which accommodates both short- and long-term impacts. Also, we utilise the Dumitrescu and Hurlin Panel Causality analysis to establish the course of causality among the examination factors.

Going by the research findings, in the long run, we find evidence of a U-shaped Environmental Kuznets Curve and a negative connection between inexhaustible power and pollutant release in the EU-11 countries. Consequently, short-run results show that exhaustible energy aggravates emissions while renewable energy leads to a fall in emissions. Similarly, Causality tests show a feedback mechanism between discharges and renewable energy use and between exhaustible vitality use and renewable energy. At the same time, there is a one-way cause from income to CO_2 release, exhaustible energy use to CO_2 release.

As regards the policy implications of the study, some suggestions have been made. Firstly, given the impact of income and renewable energy on the environment, this study calls for the implementation of a renewable energy growth framework that will grow the economy and reduce emissions simultaneously. This can be accomplished using renewable energy sources which as shown in the study, will lead to a reduction in emissions in the E11 countries. This can be achieved by giving priority to expanding the portion of renewable power in the powerful blend of the region. This will do a lot to improve the earth's standard and set the region on a path to attaining the COP25 resolution. Secondly, the study suggests that income-induced emissions can be controlled by strategic measures such as the strategic location of industries to reduce emissions from logistics, the use of renewable energy transportation to power economic activities, for example, electric trains could also go a long way to arrest the high levels of emissions. Thirdly, the imposition of carbon charge on high carbon radiating exercises such as air transport and extractive industry activities will go a long way to curbing inflation in the region. Fourthly, renewable energy consumption can predict the future of CO_2 emissions, strategies should be put in place to ensure that the roadmap to vision 2030 is strictly adhered to by the countries.

Given that over a hundred other countries are party to the Paris Agreement, we find that this study, focusing on the EU region, may be limited in serving these countries' needs as a policy reference material. To this effect, future lessons can be carried out for individual countries. Future studies should also consider using other econometric techniques to make available a wide range of materials on this topic.

Acknowledgements Gratitude is extended to the prospective editor(s) and reviewers that will/have spared time to guide toward a successful publication.

The authors of this article also assure that they follow the Springer publishing procedures and agree to publish it as any form of access article confirming to subscribe to access standards and licensing.

Many thanks in advance, looking forward to your favourable response.

Author contribution The first author (Dr Festus Fatai Adedoyin) was responsible for the conceptual construction 646 of the study's idea. The second author (Prof. Dr Andrew Adewale Alola) handled the literature section while the third author (Asst. Prof.Dr. Festus Victor Bekun) managed the data gathering, responsible for proofreading and manuscript editing.

Data availability The data for this present study are sourced from the World Development Indicators (https://data.worldbank.org/). The current data, specific data, can be made available upon request but all available and downloadable at the earlier mentioned database and weblink.

Declarations

Ethics approval and consent to participate The 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 for publication The 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.

Competing interests I wish to disclose here that there are no potential conflicts of interest at any level of this study.

References

Abdouli M, Hammami S (2017) Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. Int Bus Rev 26(2):264–278. https://doi.org/10.1016/j.ibusrev.2016.07.004

Acheampong AO (2018) Economic growth, CO_2 emissions and energy consumption: what causes what and where? Energy Econ 74:677–692. https://doi.org/10.1016/j.eneco.2018.07.022

Adams S, Klobodu EKM, Opoku EEO (2016) Energy consumption, political regime and economic growth in sub-Saharan Africa. Energy Policy 96:36–44. https://doi.org/10.1016/j.enpol.2016.05.029

Adedoyin FF, Zakari A (2020) Energy consumption, economic expansion, and CO_2 emission in the UK: the role of economic policy uncertainty. Science of The Total Environment. Retrieved from https://www.researchgate.net/publication/341902809_Energy_Consumption_Economic_Expansion_and_CO2_Emission_in_the_UK_The_Role_of_Economic_Policy_Uncertainty

Adedoyin F, Abubakar I, Victor F, Asumadu S (2020a) Generation of energy and environmental-economic growth consequences : is there any difference across transition economies ? Energy Rep 6:1418–1427. https://doi.org/10.1016/j.egyr.2020.05.026

Adedoyin FF, Alola AA, Bekun FV (2020b) 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

Adedoyin FF, Bekun FV, Alola AA (2020c) growth impact of transition from non-renewable to renewable energy in the EU: the role of research and development expenditure. Renew Energy 159:1139–1145

Adedoyin FF, Gumede IM, Bekun VF, Etokakpan UM, Balsalobre-lorente D (2020d) Modelling coal rent, economic growth and CO_2 emissions: does regulatory quality matter in BRICS economies ? Sci Total Environ 710:136284. https://doi.org/10.1016/j.scitotenv.2019.136284

Adedoyin F, Ozturk I, Abubakar I, Kumeka T, Folarin O (2020e) Structural breaks in CO_2 emissions : are they caused by climate change protests or other factors ? J Environ Manag 266(December 2019):110628. https://doi.org/10.1016/j.jenvman.2020.110628

Ahmed Z, Nathaniel SP, Shahbaz M (2021) The criticality of information and communication technology and human capital in environmental sustainability: evidence from Latin American and Caribbean countries. J Clean Prod 286:125529

Alam MM, Murad MW, Noman AHM, Ozturk I (2016) Relationships among carbon emissions, economic growth, energy consumption and population growth: testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecol Indic 70:466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Al-mulali U (2011) Oil consumption, CO_2 emission and economic growth in MENA countries. Energy 36(10):6165–6171. https://doi.org/10.1016/j.energy.2011.07.048

Antonakakis N, Chatziantoniou I, Filis G (2017) Energy consumption, CO_2 emissions, and economic growth: an ethical dilemma. Renew Renew Energy Energy Rev 68(October 2015):808–824. https://doi.org/10.1016/j.rser.2016.09.105

Apergis N, Payne JE (2014) Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: evidence from a nonlinear panel smooth transition vector error correction model. Energy Econ 42:226–232

Aydin M (2019) Renewable and non-renewable electricity consumption–economic growth nexus: evidence from OECD countries. Renew Energy 136:599–606. https://doi.org/10.1016/j.renene.2019.01.008

Bekun FV, Alola AA, Sarkodie SA (2019) Toward a renewable energy environment: nexus between CO_2 emissions, resource rent, renewable and non-renewable energy in 16-EU countries. Sci Total Environ 657:1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Belaid F, Youssef M (2017) Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: assessing the evidence from Algeria. Energy Policy 102:277–287

Ben Jebli M, Ben Youssef S, Ozturk I (2016) Testing environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries. Ecol Indic 60:824–831. https://doi.org/10.1016/j.ecolind.2015.08.031

Bilgili F, Koçak E, Bulut Ü (2016) The dynamic impact of renewable energy consumption on CO_2 emissions: a revisited Environmental Kuznets Curve approach. Renew Renew Energy Energy Rev 54:838–845. https://doi.org/10.1016/j.rser.2015.10.080

Boontome P, Therdyothin A, Chontanawat J (2017) Investigating the causal relationship between non-renewable and renewable energy consumption, CO_2 emissions and economic growth in Thailand. Energy Procedia 138:925–930. https://doi.org/10.1016/j.egypro.2017.10.141

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

Chen Y, Zhao J, Lai Z, Wang Z, Xia H (2019b) Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO_2 emissions: evidence from a regional panel analysis. Renew Energy 140:341–353. https://doi.org/10.1016/j.renene.2019.03.058

Cherni A, Essaber Jouini S (2017) An ARDL approach to the CO_2 emissions, renewable energy and economic growth nexus: Tunisian evidence. Int J Hydrog Energy 42(48):29056–29066. https://doi.org/10.1016/j.ijhydene.2017.08.072

Cowan WN, Chang T, Inglesi-Lotz R, Gupta R (2014) The nexus of electricity consumption, economic growth and CO_2 emissions in the BRICS countries. Energy Policy 66:359–368. https://doi.org/10.1016/j.enpol.2013.10.081

Destek MA, Aslan A (2017) Renewable and non-renewable energy consumption and economic growth in emerging economies: evidence from bootstrap panel causality. Renew Energy 111:757–763. https://doi.org/10.1016/j.renene.2017.05.008

Dogan E, Inglesi-Lotz R (2017) Analysing the effects of real income and biomass energy consumption on carbon dioxide (CO_2) emissions: empirical evidence from the panel of biomass-consuming countries. Energy 138:721–727. https://doi.org/10.1016/j.energy.2017.07.136

Dogan E, Seker F (2016a) The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Renew Energy Energy Rev 60:1074–1085. https://doi.org/10.1016/j.rser.2016.02.006

Dogan E, Seker F (2016b) Determinants of CO_2 emissions in the European Union: the role of renewable and non-renewable energy. Renew Energy 94:429–439

Dong K, SUN R, Hochman G (2017) Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical eveidence from a panel of BRICS countries. Energy 141(2017): 1466–1477

Du L, Wei C, Cai S (2012) Economic development and carbon dioxide emissions in China: provincial panel data analysis. China Econ Rev 23(2):371–384. https://doi.org/10.1016/j.chieco.2012.02.004

Etokakpan MU, Adedoyin FF, Vedat Y, Bekun FV (2020) Does globalisation in Turkey induce increased energy consumption : insights into its environmental pros and cons. Environ Sci Pollut Res 27: 26125–26140

Gorus MS, Aslan M (2019) Impacts of economic indicators on environmental degradation: evidence from MENA countries. Renew Renew Energy Energy Rev 103(December 2017):259–268. https://doi.org/10.1016/j.rser.2018.12.042

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

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

Inglesi-Lotz R, Dogan E (2018) The role of renewable versus non-renewable energy to the level of CO_2 emissions a panel analysis of sub- Saharan Africa's Big 10 electricity generators. Renew Energy 123:36–43. https://doi.org/10.1016/j.renene.2018.02.041

Ito K (2017) CO_2 emissions, renewable and non-renewable energy consumption, and economic growth: evidence from panel data for developing countries. Int Econ 151(February):1–6. https://doi.org/10.1016/j.inteco.2017.02.001

Jebli MB, Youssef SB, Ozturk I (2016) Testing environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries. Ecol Indic 60:824–831

Kirikkaleli D, Adedoyin FF, Bekun FV (2020) Nuclear energy consumption and economic growth in the UK: evidence from wavelet coherence approach. J Public Aff (February):1–11. https://doi.org/10.1002/pa.2130

Lipford JW, Yandle B (2010) Environmental Kuznets curves, carbon emissions, and public choice. Environ Dev Econ 15(4):417–438

Maji IK, Sulaiman C (2019) Renewable energy consumption and economic growth nexus: a fresh evidence from West Africa. Energy Rep 5:384–392. https://doi.org/10.1016/j.egyr.2019.03.005

Mirza FM, Kanwal A (2017) Energy consumption, carbon emissions and economic growth in Pakistan: dynamic causality analysis. Renew Renew Energy Energy Rev 72(October 2016):1233–1240. https://doi.org/10.1016/j.rser.2016.10.081

Munir Q, Lean HH, Smyth R (2020) CO_2 emissions, energy consumption and economic growth in the ASEAN-5 countries: a cross-sectional dependence approach. Energy Econ 85:104571. https://doi.org/10.1016/j.eneco.2019.104571

Musolesi A, Mazzanti M, Zoboli R (2010) A panel data heterogeneous Bayesian estimation of environmental Kuznets curves for CO_2 emissions. Appl Econ 42(18):2275–2287

Nathaniel SP, Adeleye N (2021) Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected African countries: implication for sustainability. J Clean Prod 285: 125409

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 SP, Murshed M, Bassim M (2021) The nexus between economic growth, energy use, international trade and ecological footprints: the role of environmental regulations in N11 countries. Energ Ecol Environ. https://doi.org/10.1007/s40974-020-00205-y

Omri A (2013) CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ 40:657–664. https://doi.org/10.1016/j.eneco.2013.09.003

Paramati SR, Sinha A, Dogan E (2017) The significance of renewable energy use for economic output and environmental protection: evidence from the next 11 developing economies. Environ Sci Pollut Res 24(15):13546–13560

Pata UK (2018) The influence of coal and noncarbohydrate energy consumption on CO_2 emissions: revisiting the environmental Kuznets curve hypothesis for Turkey. Energy 160(2018):1115–1123

Pesaran MH, Shin Y, Smith RP (1999) Pooled mean group estimation of dynamic heterogeneous panels. J Am Stat Assoc 94(446):621–634

Sadorsky P (2009) Renewable energy consumption, CO_2 emissions and oil prices in the G7 countries. Energy Econ 31(3):456–462

Salim RA, Hassan K, Shafiei S (2014) Renewable and non-renewable energy consumption and economic activities: further evidence from OECD countries. Energy Econ 44:350–360. https://doi.org/10.1016/j.eneco.2014.05.001

Sebri M, Ben-Salha O (2014a) On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: fresh evidence from BRICS countries. Renew Renew Energy Energy Rev 39:14–23. https://doi.org/10.1016/j.rser.2014.07.033

Sebri M, Ben-Salha O (2014b) On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: fresh evidence from BRICS countries. Renew Renew Energy Energy Rev 39:14–23. https://doi.org/10.1016/j.rser.2014.07.033

Shafiei S, Salim RA (2014) Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis. Energy Policy 66:547–556. https://doi.org/10.1016/j.enpol.2013.10.064

Shahbaz M, Sinha A (2019) Environmental Kuznets curve for CO_2 emissions: a literature survey. J Econ Stud 46(1):106–168

Shahbaz M, Haouas I, Van Hoang TH (2019) Economic growth and environmental degradation in Vietnam: is the environmental Kuznets curve a complete picture? Emerg Mark Rev 38(December 2018):197–218. https://doi.org/10.1016/j.ememar.2018.12.006

Sharif A, Raza SA, Ozturk I, Afshan S (2019) The dynamic relationship of renewable and non-renewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations. Renew Energy 133:685–691. https://doi.org/10.1016/j.renene.2018.10.052

Sinha A, Shahbaz M (2018) Estimation of environmental Kuznets curve for CO_2 emission: role of renewable energy generation in India. Renew Energy 119:703–711

Sinha A, Shahbaz M, Balsalobre D (2017) Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. J Clean Prod 168:1217–1229

Tamba JG (2017) Energy consumption, economic growth, and CO_2 emissions: evidence from Cameroon. Energy Sour B: Econ Plan Pol 12(9):779–785. https://doi.org/10.1080/15567249.2016.1278486

Troster V, Shahbaz M, Uddin GS (2018) Renewable energy, oil prices, and economic activity: a Granger-causality in quantiles analysis. Energy Econ 70:440–452. https://doi.org/10.1016/j.eneco.2018.01.029

Udi J, Bekun FV, Adedoyin FF (2020) Modeling the nexus between coal consumption, FDI inflow and economic expansion: does industrialisation matter in South Africa? Environ Sci Pollut Res 27:10553–10564. https://doi.org/10.1007/s11356-020-07691-x

United Nation Development programme (UNDP) (2019) The United Nations Development programme on carbon reduction. Available at United Nations Development Programme (UNDP) | Green Climate Fund (Accessed 22.06.2019)

Uzar U, Eyuboglu K (2019) The nexus between income inequality and CO_2 emissions in Turkey. J Clean Prod 227:149–157. https://doi.org/10.1016/j.jclepro.2019.04.169

Wang S, Li Q, Fang C, Zhou C (2016) The relationship between economic growth, energy consumption, and CO_2 emissions: empirical evidence from China. Sci Total Environ 542:360–371. https://doi.org/10.1016/j.scitotenv.2015.10.027

Zafar MW, Shahbaz M, Hou F, Sinha A (2019) From nonrenewable to renewable energy and its impact on economic growth: the role of research & development expenditures in Asia-Pacific Economic Cooperation countries. J Clean Prod 212:1166–1178

Zaman K, el Moemen MA (2017) Energy consumption, carbon dioxide emissions and economic development: evaluating alternative and plausible environmental hypothesis for renewable energy growth. Renew Renew Energy Energy Rev 74(November 2015):1119–1130. https://doi.org/10.1016/j.rser.2017.02.072

Zhang XH, Zhang R, Wu LQ, Deng SH, Lin LL, Yu XY (2013) The interactions among China's economic growth and its energy consumption and emissions during 1978-2007. Ecol Indic 24:83–95. https://doi.org/10.1016/j.ecolind.2012.06.004

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.