Environmental Science and Pollution Research (2023) 30:95394–95409
https://doi.org/10.1007/s11356-023-29020-8

RESEARCH ARTICLE

The impacts of renewable energy and institutional quality in environmental sustainability in the context of the sustainable development goals: A novel approach with the inverted load capacity factor

Mehmet Metin DAM[1] · Cem Işık[2,3] · Serdar Ongan[4]

Received: 24 May 2023 / Accepted: 24 July 2023 / Published online: 7 August 2023

Abstract
It is crucial to fulfill sustainable development goals in combating environmental pollution. Recently, there has been a growing literature on environmental pollution; however, while many proxies represent environmental pollution, few proxies represent environmental sustainability. In this paper, we examine the effects of institutional quality (SDG-16), economic growth (SDG-8), and renewable energy (SDG-7) on the inverted load capacity factor (SDG-13) in OECD countries from 1999 to 2018. The objective is to ensure environmental sustainability within the Sustainable Development Goals (SDGs) framework. In this respect, the study differs from the existing literature by approaching the sustainable environment literature from a broader perspective. Long-term empirical estimates from the PMG-ARDL technique have shown that institutional quality, reel income, and population increase the inverted load capacity factor, that is, decrease environmental sustainability. However, on the contrary, renewable energy decreases the inverted load capacity factor. Therefore, renewable energy consumption helps reach SDG-7 and SDG-13 in OECD countries. In addition, it is found that economic growth is significant both in the long run and in the short run, and the impact of economic growth on the environment is greater in the short run than in the long run. This result supports the environmental Kuznets curve (EKC) hypothesis for OECD countries. The panel causality test results find a bidirectional causality relationship from renewable energy and population to inverted load capacity factor and a unidirectional causality relationship from institutional quality to inverted load capacity factor. This study argues that policymakers should concentrate on deploying environmentally friendly technology to slow down environmental degradation, increase the usage of renewable energy sources, and promote sustainable development in line with the SDGs.

Keywords EKC hypothesis · Environmental sustainability · Institutional quality · Inverted load capacity factor · Renewable energy · SDGs

Responsible Editor: Arshian Sharif

✉ Cem Işık
cemisik@anadolu.edu.tr; cemisik@lau.edu.lb

Mehmet Metin DAM
metindam@adu.edu.tr

Serdar Ongan
serdarongan@usf.edu

1 Department of International Trade and Finance, Aydin Adnan Menderes University, Nazilli, 09800 Aydin, Türkiye

2 Department of Economics, Faculty of Economics and Administrative Sciences, Anadolu University, Tepebaşı, Eskişehir, Türkiye

3 Adnan Kassar School of Business, Lebanese American University, Beirut, Lebanon

4 Department of Economics, University of South Florida, Tampa, USA

Introduction

The increased demand for fossil fuels after the industrial revolution has led to a dramatic increase in global greenhouse gas emissions (GHGs) from human activities over the past few decades, nearly doubling environmental degradation compared to the pre-industrial revolution (Chhabra et al. 2023; Işık et al. 2023, 2022; Ongan et al. 2023; Ongan et al. 2022; Ongan et al. 2021; Sharif et al. 2023). Rapid action is required to stop environmental degradation and reach sustainable goals since rising fossil fuel consumption has accelerated environmental degradation (IEA 2023). Many international organizations, governments, decision-makers, and policymakers collaborate to overcome these environmental challenges and find solutions using clean energies to create a sustainable future (Işık et al. 2021a, 2021b; Sharif et al. 2022).

Governments have taken many regional and global meetings and decisions about combating environmental pollution. In this respect, the United Nations Framework Convention on Climate Change is an important decision taken within the scope of combating climate change (Bulut et al. 2023; Işık et al. 2018). In this context, the two most essential agreements made under the leadership of the United Nations are the Kyoto Protocol and the Paris Climate Agreement (Bulut et al. 2023; Işık et al. 2018). In the Kyoto Protocol, countries were obliged to reduce GHGs for the first time. In other words, the countries that took responsibility were limited to environmental protection (Ahmad and Jabeen 2023, Ahmad et al. 2023b, Ahmad et al. 2022a, Ahmad et al. 2022b, Ahmad et al. 2021; Chien et al. 2023; Dagar and Malik 2023; Dagher and Hasanov 2023; Alvarado et al. 2022a; Alvarado et al. 2022b; Alvarado et al. 2022c; Alvarado et al. 2021; Belaid et al. 2021; Işık et el. 2020, Işık et al. 2021b; Dagher et al. 2020; Dagher 2012). Climate scientists stress the significance of achieving 1.5 °C as part of the Paris climate agreement, which aims to keep the long-term increase in global temperature below 2 °C in comparison to the preindustrial era. Future forecasts at the COP26 meeting in Glasgow seek to cut emissions by 2030 and achieve net zero emissions by 2050 (Kirikkaleli et al. 2023). Despite all the efforts to combat climate change and global warming, the rapid rise in global production has increased energy and natural resources usage, expanding the ecological footprint (Bulut et al. 2023; Işık et al. 2018).

Environmental issues have regularly been discussed in research in recent years. Researchers have used many indicators to date as indicators of environmental degradation. These indicators include total GHGs, CO_2 emissions, EFP, carbon footprint, resource rent, nitrogen dioxide, sulfur dioxide, PM2.5, and PM10. Among these variables, CO_2 emissions and GHGs were used most frequently. However, since these emissions focus only on-air pollution, soil and water pollution are neglected. In this percentage, ecological pollution has been examined frequently in recent studies. The ecological footprint indicator, used as ecological pollution in these studies, is preferred because it is a more comprehensive indicator than CO_2 emissions (Pata and Işık 2021).

The EFP, which measures the amount of food, water, energy, transportation, and other materials consumed by an individual or community and their contribution to GHGs, falls short of a sustainable environment. Because water and soil pollution cause environmental problems at least as much as air pollution. In addition, analyzing the EFP alone when assessing environmental sustainability neglects the supply side of nature, and we can only calculate environmental pollution (Işık et al. 2021b). In this context, all pollution must be tackled to achieve the SDGs. For example, SDG-13 is about air pollution, SDG-14 is about water pollution, and SDG-15 is about soil pollution. In this respect, biocapacity is as vital as EFP in environmental sustainability. Biocapacity, which refers to the capacity of a region to use its natural resources sustainably, plays an essential role in balancing the ecosystem. When a region's EFP is larger than its biocapacity, it means that the region is overusing its natural resources, and its consumption is not sustainable.

Researchers, who argue that examining the EFP alone is insufficient for environmental sustainability assessment, used the load capacity factor derived by Siche et al. (2010) as an indicator of environmental quality (Shang et al. 2022).

If a country's EFP exceeds the biocapacity of its space (EFP > biocapacity), they consume more resources and produce more waste and pollution than the ecosystem can sustainably support. Figure 1 shows that in 1971, the EFP exceeded the biocapacity (EFP biocapacity ≥ 0), creating an ecological deficit that grew rapidly daily and increased the ecological deficit.

For example, while the ecological deficit was 0.30 in 1982, it increased to 1.19 in 2018, and the ecological overcapacity exceeded four times.

The EFP measures the land and water needed to produce the goods and services consumed in a country. An ecological deficit occurs when the EFP exceeds the biocapacity, the amount of land and water available to provide these resources and services. Figure 2 shows the world's ecological deficit and reserves. In most developed countries, the EFP is 150% larger than the biocapacity.

For example, according to the Global Footprint Network 2018 data for OECD countries, the EFP in Israel, South Korea, and Belgium were 25.8, 9.8, and 9 times the biocapacity, respectively. The fact that the EFP in developed countries is much higher than the biocapacity (BC) makes the load capacity factor values between 0 and 1. When the logarithm of these numbers is taken for analysis, the analysis results are biased or cannot be calculated. For this

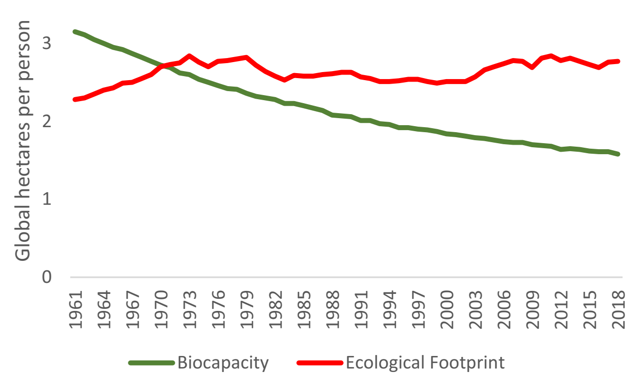


Fig. 1 World's Biocapacity and Ecological Footprint. Source: Global Footprint Network

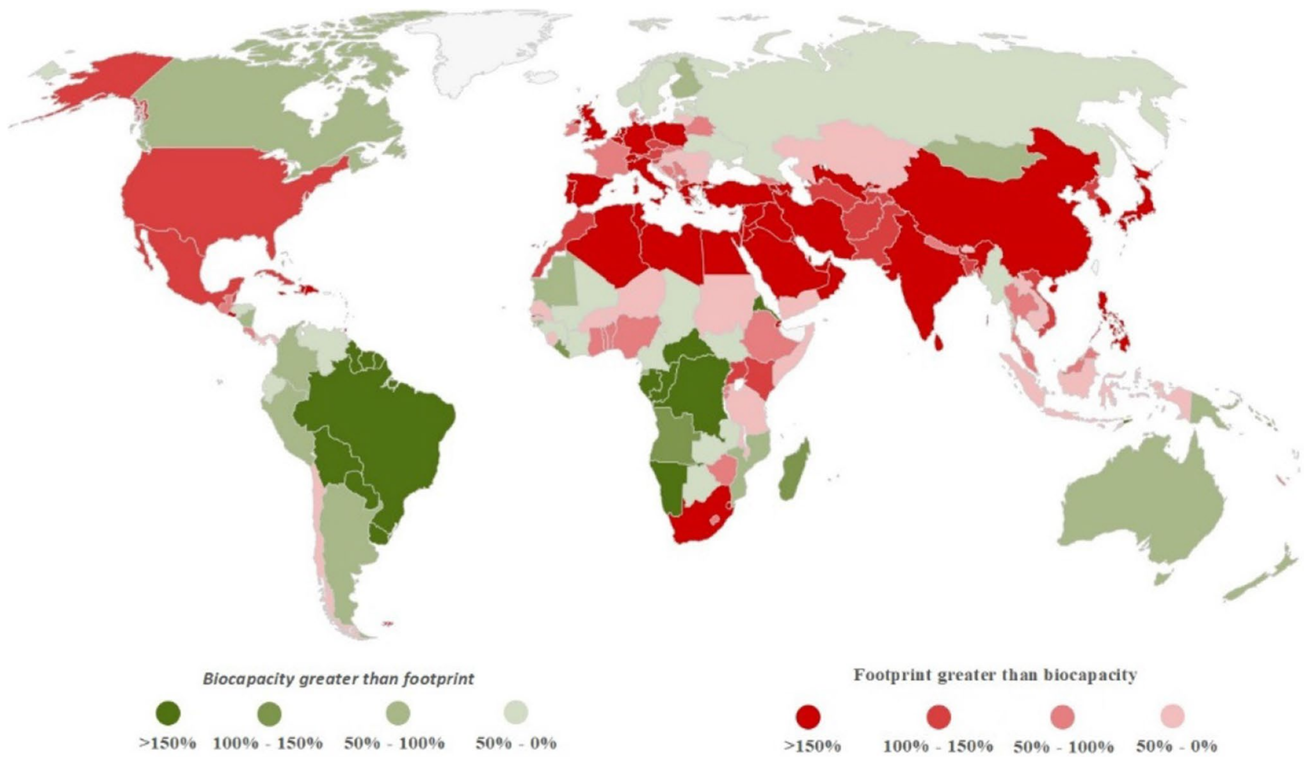


Fig. 2 World Ecological Deficit and Reserves. Source: Global Footprint Network

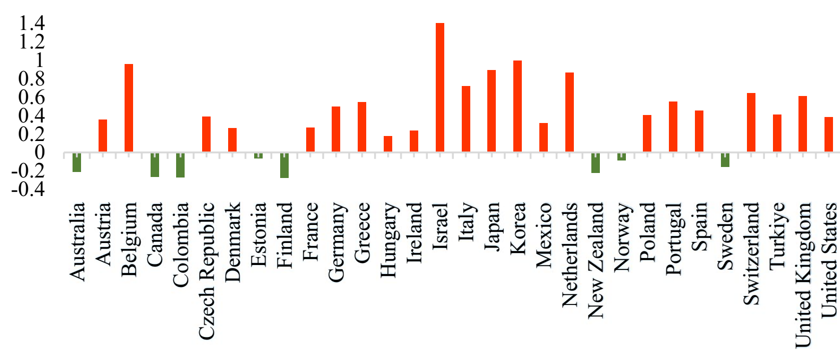
reason, instead of the load capacity factor (LCF) obtained from the BC x EFP-1 formula, the inverted load capacity factor (ILCF) obtained from the EFPxBC-1 formula gives more effective results in the analysis. LCF shows the load capacity, while ILCF shows the load capacity excess. Used for the first time in the analysis as an environmental indicator, the ILCF measures the pollution dimension of a sustainable environment.

Figure 3 shows the logarithmic reverse load capacity factor values of 30 OECD countries in 2018. In OECD countries, 8 countries (green column) with an ILFC below "0" have ecological reserves, and 22 countries (red column) with an ILFC above "0" have ecological deficits.

Since the LCF value is greater than 1 in countries with more ecological reserves, effective results can be obtained in the analysis. Siche et al. (2010), who first introduced the LCF as a proxy for a sustainable environment, analyzed the principle of Peru, which has a large ecological reserve as a sample. In addition, Pata et al. (2023a) took LCF as a proxy for a sustainable environment for Latin American and Caribbean countries and found similar results.

However, obtaining the same effective results with the LCF variable may not be possible in countries with ecological deficits. Since most countries have ecological deficits, more efficient results can be obtained with the ILCF variable. In this framework, this study explores the effects of

Fig. 3 Inverted Load Capacity Factor of 30 OECD Countries In 2018. Source: Global Footprint Network



renewable energy and institutional quality on a sustainable environment by including 22 countries of the OECD with ecological deficits.

Do existing environmental pollution proxies represent environmental sustainability? Environmental pollution proxies have focused on the demand side of environmental pollution but neglected the supply side of the ecosystem. In this context, the ILCF variable used in this study considers both the supply and demand side of the ecosystem to ensure environmental sustainability. This study examines the effect of institutional quality, economic growth, and renewable energy on environmental sustainability with annual data from 1999 to 2018 in OECD countries using ARDL and DHPC methods. This study differs from the literature for the following reasons: First, we created a new proxy called ILFC to measure Environmental sustainability. This variable is more comprehensive than the previous environmental pollution variables as it captures environmental quality's supply and demand characteristics. Second, The ILFC variable gives more comprehensive and consistent results than the LCF variable. This is because most countries in the world have an ecological deficit, and the size of this deficit is large. Third, it is the first study to test the EKC hypothesis for ILFC according to the approach of Narayan and Narayan (2010). In this study, the EKC hypothesis is valid in OECD countries. Fourthly, the impact of institutional quality (IQ), economic growth (GDP), renewable energy consumption (REC), and population (POP) on ILFC in OECD countries using annual data from 1999 to 2018 is analyzed by the ARDL cointegration method. Finally, this study will help policymakers and decision-makers formulate appropriate environmental and energy policies by considering the effects of REC, IQ, GDP, and POP. For these reasons, research of this nature, in which sustainable environment (SDG-13) is modeled as the dependent variable and IQ (SDG-16), renewable energy consumption (SDG-7), and economic growth (SDG-8) as independent variables, which require urgent action to combat climate change, is timely and valuable.

The study proceeds as follows: "Literature review" section presents the literature review, "Data, model description, and methodology" section presents the data, model identification, and methodology, "Results and discussion" section presents the results and discussion, and "Conclusions and policy recommendation" section presents the conclusions and policy recommendations.

Literature review

REC is a critical component of environmental sustainability. Renewable energy sources reduce dependence on non-renewable energy (NREC) sources such as fossil fuels. This, in turn, reduces GHGs and helps mitigate the effects of climate change. Furthermore, renewable energy technologies are becoming increasingly affordable and accessible, making them an attractive option for individuals, businesses, and governments. In addition to reducing carbon emissions, renewable energy sources have other environmental benefits, such as reducing air and water pollution and reducing the environmental impacts of energy production.

Environmental sustainability and IQ are closely linked because effective institutions are necessary to promote sustainable practices and address environmental challenges. Countries with strong IQs are better equipped to implement and enforce environmental regulations, promote sustainable development policies, and manage natural resources effectively. In the fight against environmental pollution, it is crucial to improve IQ and REC. The relationship between IQ and REC and environmental sustainability is discussed separately.

Institutional quality and environmental sustainability

Many factors drive the quality of a country's institutions. These factors include public concerns, the rule of law, strict government regulation, regulatory quality, political stability, and control of corruption (Khan et al. 2021). Studies on the environment-IQ relationship have increased in the last decade. There is a close relationship between a country's environment and the quality of its institutions because countries with weak environmental laws will have increased environmental pollution (Egbetokun et al. 2020).

Studies in the literature show that IQ is an essential determinant of environmental degradation. Therefore, countries with stronger institutions can better enforce environmental regulations, protect property rights, promote sustainable development, and ensure public participation in environmental decision-making.

Karimi Alavijeh et al. (2023) investigated the effect of IQ on environmental pollution in EU countries between 2000–2019 and concluded that IQ reduces environmental pollution. However, Le and Ozturk (2020) examined the effect of IQ on CO_2 emissions in developing countries from 1990–2014 and concluded that IQ has an increasing effect on CO_2 emissions. Safi et al. (2022) investigated the effects of IQ on environmental pollution in E-7 economies for the period 1995–2019 with CS-ARDL and AMG methods. They found a positive relationship with the CS-ARDL method and a negative relationship with the AMG method.

Ni et al. (2022) analyzed the impact of IQ, GDP, natural resources, and digitalization on LCF for the period 1965–2018 for high-resource-consuming economies with the CS-ARDL method, and because of the analysis, natural resources and GDP decreased LCF, while digitalization and good governance improved LCF.

While Le and Ozturk (2020) found a bidirectional causality relationship between IQ and environmental pollution, Udeagha and Ngepah (2022) and Yang et al. (2022), on the other hand, a unidirectional causality relationship was determined. Table 10 in the appendix summarizes selected studies linking IQ and environmental degradation.

Renewable energy consumption and environmental sustainability

Energy use, the most essential input for producing goods in a country, is increasing daily. Since the need for energy is very high, both NREC and REC are increasing. Energy from fossil fuels is unsustainable because it is more accessible and cheaper. In contrast, renewable energy sources are expensive but sustainable (Alvarado et al. 2022b). Countries encourage using alternative energies due to energy scarcity, population growth, energy efficiency, global warming, and climate change (Karimi Alavijeh et al. 2023).

In previous studies in the literature, total energy consumption was included in the model as a proxy for energy consumption (Ozturk and Acaravci 2010; Pao and Tsai 2010). However, in recent studies, REC reduces environmental pollution, while NREC has an increasing effect on environmental pollution (Habiba et al. 2022; Obobisa et al. 2022). Therefore, research on REC is rapidly growing among researchers (Alvarado et al. 2022b). REC, which plays an essential role in sustainable development, is indispensable in countries that seek to improve the quality of the environment as part of sustainable development policies. Many studies have suggested that REC helps reduce environmental degradation (Liu et al. 2022).

Theoretical and conceptual framework

In the twenty-first century, population, technology, and economic growth have grown enormously, but with them have come many challenges that threaten the world, notably environmental problems. Sustainable development is a structural reform in solving these problems (Fukuda-Parr 2016). The term "sustainable development" was first used in the 1980s by environmental activists and scientists who drew attention to environmental issues worldwide (Hák et al. 2016). This expression focuses on the importance of intergenerational resource equality through resource efficiency. At the same time, sustainability is a crucial part of sustainable development, and its implementation is necessary to preserve and improve the quality of life of future generations.

The Millennium Development Goals (MDGs) and the SDGs are two sets of development goals that the United Nations has established. While the MDGs were introduced in 2000 and had a deadline of 2015, the SDGs were introduced in 2015 and are set to be achieved by 2030 (Sachs 2012). The MDGs consist of 8 goals: hunger, education, women's rights, child mortality, infectious diseases, sustainable environment, and global cooperation. In 2005, the United Nations committed to reviewing progress toward the MDGs and set a deadline for achieving the MDGs by 2015 (Sachs and McArthur 2005).

The SDGs are based on the MDGs and consist of 17 goals and 169 targets covering a wide range of issues such as climate change, sustainable consumption and production, and peace and justice. The SDGs are broader and more ambitious than the MDGs and aim to achieve a sustainable future for all people and the planet (Kumar et al. 2016). A buzzword these days, the SDGs have become a research topic for scholars and a problem-solving guide for policymakers (Wahab et al. 2022). While there are similarities between SDGs and MDGs, they differ from MDGs in terms of goals, concepts, and policies (Fukuda-Parr 2016). When the world's current load capacity is analyzed, environmental issues in implementing the United Nations SDGs have attracted attention. Economic development, environmental sustainability, and socio-cultural factors are the three broad categories of the SDGs (Sachs 2012; Rehman et al. 2021a). Particularly economic growth (SDG-8), renewable energy consumption (SDG-7), and institutional quality (SDG-16) play an essential role in collectively achieving global climate change targets and protecting the environment (SDG-13).

Effective management of environmental resources is a major problem for the sustainable development of OECD countries. In this context, one of the critical problems of OECD countries is overconsumption. Therefore, to reduce the negative environmental effects of human activities, increasing the efficiency of resource consumption is crucial (Azam et al. 2021). In this context, for OECD countries to achieve SDG-7 by 2030, decision-makers should encourage and support renewable energy investments, especially wind and solar, increase clean energy efficiency, and support technology-based clean and efficient energy sources as determinants of economic growth in all OECD countries (Cao et al. 2022). Furthermore, OECD governments should strengthen IQ and ensure the active participation of their members in formulating, monitoring, and evaluating environmental sustainability policies (Christoforidis and Katrakilidis 2021).

The SDG framework, especially the indicators, must be conceptually and methodologically well-designed and tested before adoption (Hák et al. 2016). In this context, in the empirical analysis conducted on OECD countries between 1999–2018, the following hypotheses are tested by including the ILCF variable (SDG-13), which is an indicator of environmental quality, institutional quality (SDG-16), economic growth (SDG-8) and renewable energy consumption (SDG-7) as independent variables in the model.

H1. According to the general view in the literature, the increase in real income in OECD countries increases ILCF.
H2. Renewable energy consumption in OECD countries positively affects environmental quality in line with expectations.
H3. The quality of institutions in governments affects environmental sustainability.
H4. Population growth negatively impacts environmental quality.

This study tests the effects of independent variables on ILCF using the PMG-ARDL approach to test the above four hypotheses.

Data, model description, and methodology

Data description, and model construction

In the analysis of the study, by applying yearly panel data between 1999–2018, the effects of IQ, GDP, REC, and POP on environmental sustainability are investigated in 22 OECD countries with reverse LCF values greater than 0 shown in Fig. 2. In the study, ILFC was used to measure environmental sustainability and inspired by the LFC developed by Siche et al. (2010), is used as the dependent variable. This indicator used as the dependent variable is captured as EF/BC. Various studies have been conducted to identify the key factors contributing to environmental pollution. However, research has ignored the role of IQ in achieving the SDGs. IQ refers to the overall quality of a country's institutions, including the legal system, government, regulatory framework, and other institutions that shape the country's economic and social policies. Some indicators often used to measure IQ is corruption control, government effectiveness, the rule of law, supervision quality, suitability to comment, and political stability. The values of these indicators are close to each other. In this study, government effectiveness is preferred as an indicator of IQ. Table 1 provides detailed information on the variables.

We converted all variables to natural logarithms in order to obtain reliable and consistent results in the analysis results. Table 2 reports the correlation matrix and descriptive statistics.

In Table 2, POP is the variable with the highest mean among the series in which we used annual data for 1999–2018 in OECD countries. However, the ILFC has the lowest mean. POP has the highest maximum value, while REC has the lowest maximum value. When we analyze the minimum values of the series, only REC has negative values, while all other variables have positive values. When we examine the correlation matrix, REC affects ILCF negatively, while other independent variables affect ILCF positively. Variance inflation factor (VIF) analysis is applied to check whether there is a multicollinearity problem among the independent variables used in the analysis of our study. VIF analysis results are presented in Table 3.

According to the test results in Table 3, the VIF value is less than 5, indicating no multicollinearity problem among the series. This empirical study investigates the impact of REC, IQ, GDP, and POP on environmental sustainability in OECD countries. The mathematical function

Table 2 Descriptive statistics and correlation matrix

	lnILCF	lnIQ	lnGDP	lnREC	lnPOP
Mean	0.545	1.915	4.440	0.918	7.412
Median	0.476	1.942	4.523	0.958	7.407
Max	1.425	2.000	4.938	1.552	8.514
Min	0.118	1.631	3.777	-0.161	6.574
Std. Dev	0.290	0.069	0.271	0.387	0.556
Skewness	0.864	-1.039	-0.580	-0.770	0.247
Kurtosis	3.248	3.440	2.454	3.454	1.868
Jarque–Bera	55.907[a]	82.731[a]	30.142[a]	47.327[a]	27.985[a]
Prob	0.000	0.000	0.000	0.000	0.000
lnILCF	1.000				
lnIQ	0.222***	1.000			
lnGDP	0.274***	0.841***	1.000		
lnREC	-0.461***	-0.103**	-0.044	1.000	
lnPOP	0.012	-0.258***	-0.174***	-0.205***	1.000
Obs	440	440	440	440	440

*** and ** refer to significance at the 1 and 5 percent levels, respectively. "a" represents the rejection of the null of normality at 1% levels

Table 1 Data description and sources

Variables	Symbol	Description and Measurement	Source
Inverted load capacity factor	ILCF	Ecological footprint/biocapacity, (gha per person)	Global Footprint Network (2023)
Institutional quality	IQ	Government effectiveness	WGI (2023)
Economic growth	GDP	GDP per capita (constant 2015 US$)	WDI (2023)
Renewable energy consumption	REC	% of total final energy consumption	✓
Population	POP	Total Individuals	✓

Table 3 Multi-collinearity test results

Variable	Tolerance	VIF
lnIQ	0.270	3.70
lnGDP	0.286	3.49
lnREC	0.868	1.15
lnPOP	0.921	1.09

and econometric model of the empirical analysis are as follows (Eqns. 1 and 2):

$$lnILCF_{it} = f(lnIQ_{it}^{\beta_{1i}}, lnGDP_{it}^{\beta_{2i}}, lnREC_{it}^{\beta_{3i}}, lnPOP_{it}^{\beta_{4i}}) \quad (1)$$

$$lnILCF_{it} = \alpha_0 + lnIQ_{it}^{\beta_{1i}} + lnGDP_{it}^{\beta_{2i}} + lnREC_{it}^{\beta_{3i}} + lnPOP_{it}^{\beta_{4i}} + \varepsilon_{it} \quad (2)$$

In Eq. 2, α_0; symbolizes the constant term, ε_{it}; displays the simultaneous error term, i; the cross-section and t; the time periods. $\beta_1 \rightarrow \beta_4$ show the elasticity of ILFC in response to the concerned explanatory variables. The analysis period of this study covers the period from 1999–2018.

Methodology process

In panel data analysis, a cross-sectional dependence (CSD) test should be performed first to select the appropriate unit root and estimator. If a shock to one variable affects other units, a CSD problem arises between series. Therefore, in this case, 2nd generation unit root tests should be chosen instead of 1st generation unit root tests (Pesaran 2007; Pesaran and Yamagata 2008). In this study, we test for CSD between series using Breusch-Pagan LM, bias-corrected scale LM, and Pesaran's CD tests (Breusch and Pagan 1980; Baltagi et al. 2012; Pesaran 2021). Then, appropriate unit root tests were selected according to the results of the CSD test.

We used the PMG-ARDL approach developed by Pesaran et al. (1999) to evaluate the short and long-term relationship. The PMG-ARDL estimator indicates whether the series are integrated with I(0)/I(1) or a mixture of both. In addition, we tested whether there is causality between the series or the direction of causality. In the picture, Fig. 4 maps the econometric methodology of this study.

Panel estimators

Since the series are stationary at different levels in the unit root test results, the long- and short-term estimates were analyzed using the PMG-ARDL method found by Pesaran et al. (1999). In addition, the PMG-ARDL method provides more efficient and robust results due to the correlation problems between the independent variables and the white noise term in the ARDL method.

Pesaran et al. (1999) developed the PMG-ARDL (p, q) model, which includes the long-term relationship between the series, as in the Eq. (3):

$$\Delta Y_{1it} = \alpha_{1i} + \beta_{1i} Y_{1it-1i} + \sum_{l=2}^{k} \beta_{1i} X_{1it-1} + \sum_{j=1}^{p-1} Y_{1ij} \Delta Y_{1it-j} + \sum_{j=0}^{p-1} \sum_{l=2}^{k} Y_{1ij} \Delta X_{1it-j} + \varepsilon_{1it} \quad (3)$$

Here, Y_1; the dependent variable, X_1; independent variable, Δ: the first difference operator and ε_{it}: the error term. If the equation is rearranged by adding the dependent and independent variables in the study to Eq. (3):

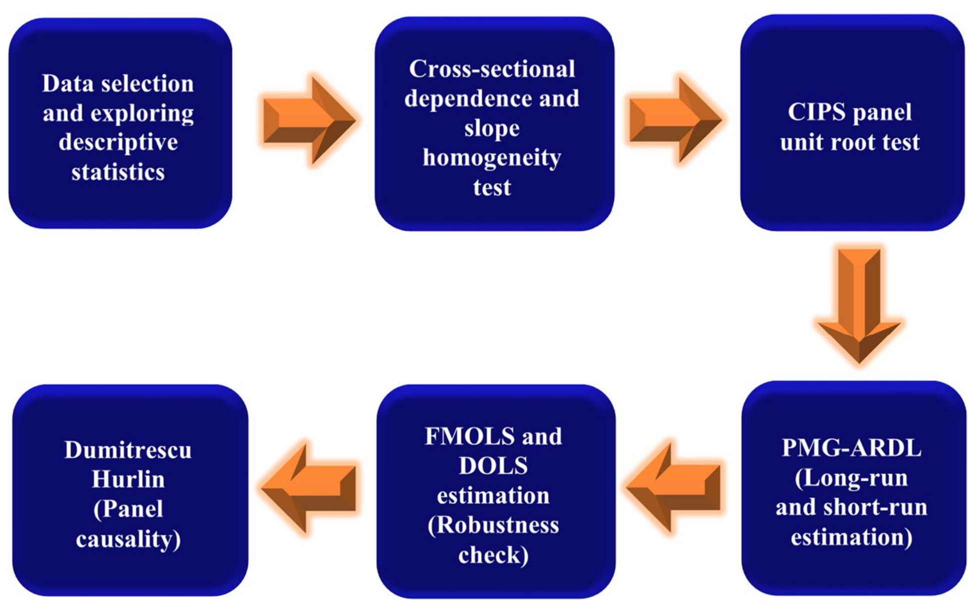


Fig. 4 Econometric framework

$$\Delta lnILFC_{it} = \alpha_{1i} + \beta_{1i}lnILFC_{it-1i} + \beta_{2i}lnIQ_{it-1} + \beta_{3i}lnGDP_{it-1} + \beta_{4i}lnREC_{it-1} + \beta_{5i}lnPOP_{it-1} + \sum_{j=1}^{p} Y_{1i}\Delta lnILFC_{it-j} + \sum_{i=0}^{q} Y_{2i}\Delta lnIQ_{it-j} + \sum_{i=0}^{q} Y_{3i}\Delta lnGDP_{it-j} + \sum_{i=0}^{q} Y_{4i}\Delta lnREC_{it-j} + \sum_{i=0}^{q} Y_{5i}\Delta lnPOP_{it-j} + \varepsilon_{1it} \quad (4)$$

Panel causality test

Many causality tests are used in the literature to question the causal relationship between variables. The Dumitrescu Hurlin Panel Causality Test (DHPC), frequently preferred recently, is applied in this study. In the DHCP test, the Zbar test represents the normal distribution, and the Wbar test represents the mean (Dumitrescu and Hurlin 2012). The following equation expresses the DHPC test:

$$Z_{it} = \alpha_i + \sum_{j=1}^{p} \beta_i^j Z_{it-j} + \sum_{j=1}^{p} \gamma_i^j T_{it-j} \quad (5)$$

where j represents the lag length and β_i^j represents the autoregressive parameters.

The H_0 and H_1 hypotheses of this test are as follows:

$H_0 : \beta_i^{(k)} = 0 \text{ for } i$ No causality,

$H_1 : \beta_i^{(k)} = 0, i = 1, 2, \dots . N_1$; $\beta_i^{(k)} \neq 0, i = N_1 + 1, N_1 + 2, N_1, \dots . N$ Unidirectional causality.

Results and discussion

Pre-estimation test results

CSD and homogeneity tests are performed between the series before performing the unit roots test in panel data analysis, and appropriate unit root tests are determined. A slope homogeneity test is applied in this study, and the results are presented in Table 4.

According to the results in Table 4, delta (Δ) and corrected delta (Δadj) values confirmed that the slope coefficients were not homogeneous, and it was decided to apply CSD tests that consider heterogeneity.

In panel data analysis, the CSD between the series is examined in the first stage with different tests. If there is CSD between sets, methods that consider this should be used because if not, the results may be biased and inconsistent (Pata et al. 2023b). Therefore, we used the Breusch-Pagan LM (BP-LM), bias-corrected scaled LM (BCS-LM), and Pesaran CD (P-CD) tests developed by Breusch and Pagan (1980) to test for horizontal CSD of the series Baltagi et al. (2012) and Pesaran (2021).

The results presented in Table 5 confirm the CSD between series. The H_0 hypothesis is strongly rejected for all series in all three tests. This shows that a possible shock in the electoral states also affects others.

Panel unit root test results

According to the slope homogeneity and CSD test results, it was decided to apply the 2nd generation unit root test. Therefore, the unit root CIPS was chosen for this analysis.

In Table 6, while ILFC, IQ and GDP series are stationary at I(1) level, REC and POP series are stationary at I(0) level in OECD countries. The fact that the series are stationary at different levels helps the application of the PMG-ARDL method.

Panel estimator results

The PMG-ARDL method was used to determine the results of the long-term and short-term estimates of the panel data analysis, and the results are shown in Table 7.

In Table 7, REC is negative and significant at the 1% level of ILCF in the long run. Namely, a 1% increase in

Table 4 Slope homogeneity test results

Test	Value	Prob
Δ	11.430***	0.000
Δ_{adj}	13.661***	0.000

*** refer to significance at the 1 percent level

Table 5 CSD test results

Variables	BP-LM	BCS-LM	P-CD
lnILCF	974.457 (0.000)***	34.009 (0.000)***	16.027 (0.000)***
lnIQ	652.626 (0.000)***	19.036 (0.000)***	-1.674 (0.000)*
lnGDP	3043.182 (0.000)***	130.255 (0.000)***	46.275 (0.000)***
lnREC	3493.715 (0.000)***	151.216 (0.000)***	35.279 (0.000)***
lnPOP	2906.734 (0.000)***	123.907 (0.000)***	24.435 (0.002)***

*** and * refer to significance at the 1 and 10 percent levels, respectively

Table 6 CIPS unit root test results

Variable	CIPS	
	Level	Δ
lnILCF	-2.119	-4.793***
lnIQ	-2.322	-4.701***
lnGDP	-1.982	-2.693***
lnREC	-2.492***	–
lnPOP	-3.292***	–

*** refer to significance at the 1 percent level

Table 7 PMG-ARDL estimation results

Variables	Coefficient	t-Stat	Prob
Long run results			
$lnIQ_{it}$	0.250***	2.684	0.007
$lnGDP_{it}$	0.276***	6.910	0.000
$lnREC_{it}$	-0.195***	-15.013	0.000
$lnPOP_{it}$	1.089***	8.590	0.000
Short run results			
ECT_{t-1}	-0.512***	-6.601	0.000
$\Delta lnIQ_{it}$	-0.050	-0.354	0.723
$\Delta lnGDP_{it}$	0.741***	4.082	0.000
$\Delta lnREC_{it}$	0.001	0.055	0.955
$\Delta lnPOP_{it}$	2.777	1.399	0.162
Constant	-4.664	-6.589	0.000

*** refer to significance at the 1 percent level

the REC reduces the ILCF by 0.195% in the long run. There is substantial evidence that REC positively impacts environmental quality in OECD countries. In the literature, Anwar et al. (2021), Liu et al. (2022), and Warsame et al. (2022) studies identified a similar effect of REC on environmental degradation. The results show that IQ positively affects ILFC in OECD countries in the long run at the 1% significance level. In other words, a 1% increase in IQ increases ILCF by 0.250% in the long run. A similar increasing effect of IQ on environmental degradation is concluded by Le and Ozturk (2020), Obobisa et al. (2022), and Wenlong et al. (2022). We then conclude that the effect of GDP and POP on environmental degradation is positive and statistically significant. A 1% increase in GDP increases ILCF by 0.250% and 0.741% in the long and short run, respectively. A 1% increase in POP increases ILCF by 1.089% in the long run. Anwar et al. (2021), Liu et al. (2022), and Warsame et al. (2022) support the results of our analysis.

If we look at the short-term results in Table 7, we can see that ECT is negative and significant, meaning there is a symmetrical cointegrating relationship. These results support studies in the literature and show that the system converges back to equilibrium in the long run after any shock. Table 7 also shows that since the long-run income elasticity is lower than the short-run income elasticity, the EKC hypothesis is valid in OECD countries, according to Narayan and Narayan (2010). In other words, GDP growth reduces the ILCF in OECD countries.

In this study, FMOLS and DOLS tests were analyzed to check the consistency and robustness of the prediction result. The FMOLS and DOLS results are presented in Table 8.

When the FMOLS and DOLS test results in Table 8 are examined, it is seen that they are consistent with the PMG-ARDL test results. Only in the FMOLS test is the effect of POP on ILCF as positive as in the PMG-ARDL test, but the effect is weaker.

Panel causality test results

In this study, we use the DHPC heterogeneous panel causality test to investigate whether there is a causal relationship between the dependent and independent variables, as in other related literature. Table 9 shows the results of the causality test.

The results indicate a bidirectional causal relationship between REC and ILFC. REC positively promotes environmental sustainability. Similar to the results obtained, Chu (2022) finds a bidirectional causal relationship between REC and environmental pollution in OECD countries. In addition, the analysis shows a unidirectional causal relationship between IQ and ILCF. Ahmad et al. (2022a) obtained similar results to our analysis of developing countries. Finally, although a unidirectional causal relationship was found between POP and ILFC, no causal relationship was found between GDP and ILFC. A graphical representation of the causality of the long-term results and our analysis results can be seen in Fig. 5.

Table 8 FMOLS and DOLS robustness test results

Variable	FMOLS	DOLS
$lnIQ_{it}$	0.288** 2.536 (0.011)	0.498* 1.924 (0.057)
$lnGDP_{it}$	0.387*** 6.409 (0.000)	0.117 1.274 (0.206)
$lnREC_{it}$	-0.115*** -8.756 (0.000)	-0.055** -2.097 (0.038)
$lnPOP_{it}$	0.256* 1.915 (0.056)	0.296 1.367 (0.175)

***, ** and * refer to significance at the 1, 5, 10 percent level, respectively

Table 9 DHPC test results

No	Null hypothesis (H_0)	W-Statistic	Zbar-Stat	Prob	Causality
1	lnIQ ≠ lnILFC	5.403	1.870	0.061*	lnIQ → lnILFC
2	lnILCF ≠ lnIQ	3.013	-0.833	0.404	None
3	lnGDP ≠ lnILFC	4.479	0.825	0.409	None
4	lnILFC ≠ lnGDP	3.448	-0.340	0.733	None
5	lnREC ≠ lnILFC	6.734	3.376	0.000***	lnREC → lnILFC
6	lnILFC ≠ lnREC	7.433	4.167	0.000***	lnILFC → lnREC
7	lnPOP ≠ lnILFC	5.997	2.543	0.011**	lnPOP → lnILFC
8	lnILFC ≠ lnPOP	7.567	4.319	0.000***	lnILFC → lnPOP

***, ** and * refer to significance at the 1 percent level, respectively

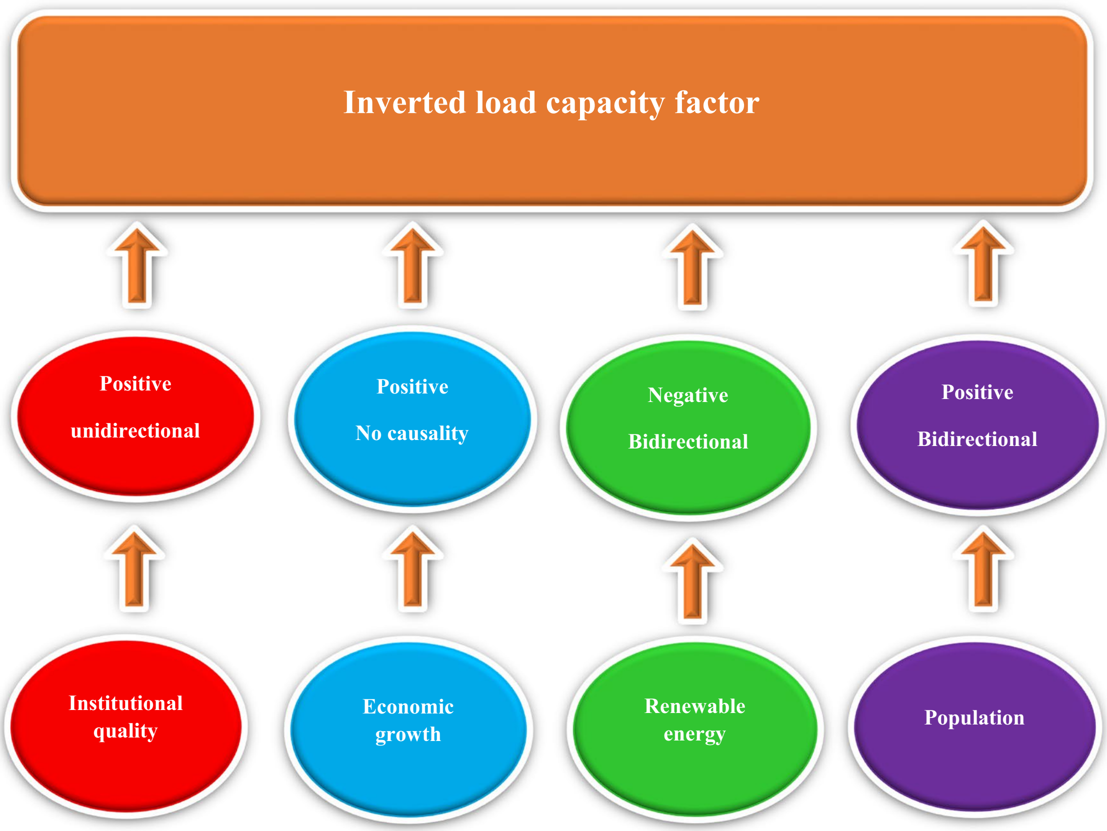


Fig. 5 Graphical representation of long run and causality results

Conclusions and policy recommendation

Previous studies on environmental sustainability have usually used variables such as CO_2 emissions, GHGs, and EFP as indicators of environmental quality. However, these variables neglect the supply side of nature when calculating environmental pollution. In this context, the contribution of environmental resources should be addressed to demonstrate true environmental sustainability. Recently, to solve these problems, researchers such as Shang et al. (2022) used the LCF developed by Siche et al. (2010) as the proxy for environmental sustainability. However, the increasing ecological deficit of the countries decreased the LCF value, and problems were experienced in these values whose logarithms were taken for analysis. To solve these problems and as the proxy of environmental sustainability, we created the ILCF variable. The ILCF variable, like the LCF variable, takes nature's supply and demand aspects. This variable is calculated as EFP divided by BC. An ILCF value greater than 1 indicates that the environmental quality of the country/countries is unsustainable.

Environmental sustainability has recently become the focus of researchers' attention compared to other SDG issues (Altunöz 2023; Çetin et al. 2023; Dogru et al. 2023a, 2023b; 2020, Dogru et al. 2019a; Dzafic and Omerbašić 2023; Faroog, et al. 2023; Islam et al. 2023; Jabeen et al. 2023; Jiang et al. 2023; Jie et al., 2023; Piwowar-Sulej et al. 2023; Rao et al. 2023; Razzaq et al. 2023; Rehman et al. 2023; Ahmad and Wu 2022; Deng et al., 2022; Rehman et al. 2022; Rehman et al. 2021a; Rehman et al. 2021b; Avci and Sarıgül, 2022; Işık 2010, 2013; Işık and Radulescu 2017; Işık et al. 2017, 2019a, b). In addition to energy use, economic growth, trade openness, and financial development, factors such as renewable energy and IQ also play an essential role in environmental sustainability. Since the creation of the SDGs, OECD countries trying to reduce their carbon emissions and improve environmental sustainability have struggled to meet the SDG targets. This study examines the factors affecting the ILCF in 22 OECD countries from 1999 to 2018. This study uses independent variables, including IQ, GDP, REC, and POP. The PMG-ARDL bounds test approach was used for long and short-run forecasts of the series, and the DHPC test was used for the causality relationship between the series. In the PMG-ARDL test results, it has been determined that REC reduces the ILCF in the long term. On the contrary, it has been found that GDP, IQ, and POP increase the ILFC in the long run. Therefore, the DHPC test was applied to determine the causality relationship among the series. According to the DHPC test results, a bidirectional causality relationship exists between REC and POP to ILFC. However, a unidirectional causality relationship was detected from IQ to ILFC, while no causality relationship was detected from GDP to ILFC. The validity of the EKC hypothesis in OECD countries emphasizes that environmental quality will improve over time. Therefore, essential to the world economy, OECD countries should focus on environmental regulations while increasing their income.

This study draws some important implications for policymakers. First, OECD countries must take more challenging and stringent measures against environmental degradation to achieve the SDGs. Considering that resource efficiency and conservation significantly reduce environmental pollution, resource efficiency and conservation in OECD countries should be supported, and these countries should be directed toward environmental research and development activities.

Since REC reduces the ILCF, which is the overcapacity of the LCF, OECD governments running ecological deficits should provide the necessary funds for R&D, innovation, and infrastructure spending to develop these energy types. In this context, decision-makers of OECD countries should improve the share of REC in total energy. Furthermore, these countries should ensure price stability in clean energy and reduce clean energy prices to achieve SDG-7 targets related to REC among the SDGs. Considering that REC reduces ILCF in OECD countries, it can be concluded that they both fulfill the SDG-13 target, and REC has a high share in achieving SDG-7. Therefore, these countries need to improve the share of REC in their total energy consumption.

OECD countries should adopt more challenging and stringent measures to prevent environmental pollution to achieve SDGs. Since resource efficiency and conservation has a significant impact on reducing environmental pollution, it is crucial to support REC practices in OECD countries and channel them into environmental research and development activities.

In light of the information obtained in this study, policymakers and decision-makers in OECD countries should not deviate from environmental sustainability targets while ensuring sustainable economic growth. Given that the REC has reduced the ILCF, which represents excess capacity in the LCF, OECD governments with ecological deficits should allocate the necessary funds for R&D, innovation, and infrastructure investments to promote these forms of energy. In this context, OECD countries should aim to increase the share of RECs in their total energy consumption.

This study has some innovations. First, the ILCF variable is taken as an indicator of environmental sustainability. In future research, new studies can be conducted using different methods and samples with the ILCF variable, considering both the environment's supply and demand dimensions. In this respect, this study will serve as a resource for future studies.

Appendix

Table 10 Studies focusing on the impact of institutional quality on environmental degradation

Study	Region	Time period	Variables	Methodology	Long run results	Causality relationship results
Ahmed et al. (2020)	Pakistan	1996–2018	CO_2, TO, FD, IQ	ARDL, NARDL	IQ, IQ (+), IQ (-), FD (+) and TO, decrease CO_2; FD and FD(-) increase CO_2	Not investigated
Le and Ozturk (2020)	47 Emerging Market and Developing Economies	1990–2014	CO_2, GDP, EC, GLO, FD, GOV, IQ	AMG, CCEMG, DCCE; DHPC	GDP, EC, GOV, IQ, KOF and FD increase CO_2	GDP, EC, GLO, FD, GOV and IQ $\leftrightarrow CO_2$
Anwar et al. (2021)	G-7 Countries	1996–2018	CO_2, GDP, REC, RD, IQ, POP	AMG, FGLS	REC, RD, and IQ decrease CO_2; GDP and POP increase CO_2	Not investigated
Bakhsh et al. (2021)	40 Asian countries	1996–2016	CO_2, GDP, EC, TI, FDI, IQ, FD, TO	GMM	IQ, TI decrease CO_2; GDP, EC, FD, FDI increase CO_2; TO mixed CO_2	Not investigated
Haldar and Sethi (2021)	Developing countries	1995–2017	CO_2, GDP, IQ, FD, REC, FDI, TO, POP	SYS-GMM, MG, AMG, CCEMG, FMOLS	GDP increase CO_2; REC and POP mixed CO_2	Not investigated
Hussain and Dogan (2021)	BRICS countries	1992–2016	EFP, GDP, EC, IQ, TI	CS-ARDL, AMG, CCEMG	IQ and TI decrease EFP; GDP and EC increase EF	Not investigated
Khan et al. (2021)	188 countries	2002–2018	CO_2, GDP, EC, IQ, FD, REC, FDI, POP, TI	GMM, SYS-GMM	REC and FDI decrease CO_2; GDP, EC, TI and FD increase CO_2; IQ and POP mixed CO_2	Not investigated
Islam et al. (2021)	Bangladesh	1972–2016	CO_2, GDP, EC, GLO, TO, FDI, TI, URB, IQ	D-ARDL	GLO and FDI, decrease CO_2; IQ insignificant CO_2	Not investigated
Ahmad et al. (2022b)	Emerging countries	1984–2017	EFP, GDP, EC, FD, HC, IQ	CS-ARDL, AMG; Granger causality	IQ and HC decrease EFP; GDP, EC and FD increase EFP	GDP and EC $\leftrightarrow$ EFP; FD, IQ and HC $\rightarrow$ EFP
Jianguo et al. (2022)	OECD economies	1998–2018	CO_2, GDP, EC, FD, FDI, TI, IQ, TO	SYS-GMM	IQ and TI decrease CO_2; EC, FD, FDI increase CO_2; GDP and TO mixed CO_2	Not investigated
Liu et al. (2022)	Emerging 7 economies	1996–2018	CO_2, GDP, REC, IQ, TI, POP	FGLS, PQR	REC, IQ and TI decrease CO_2; GDP and POP increase CO_2	Not investigated
Obobisa et al. (2022)	African countries	2000–2018	CO_2, GDP, TI, REC, NREC, IQ	AMG, CCEMG	REC and TI decrease CO_2; GDP, NREC and IQ increase CO_2	Not investigated
Udeagha and Ngepah (2022)	South Africa	1960–2020	CO_2, GDP, EC, FID, ECO, IQ, TO, POP	CCR, FMOLS, DOLS; FDC	FID, ECO and IQ decrease CO_2; GDP, EC, TO and POP increase CO_2	GDP, FID, ECO, EC, POP, IQ and TO $\rightarrow CO_2$

Table 10 (continued)

Study	Region	Time period	Variables	Methodology	Long run results	Causality relationship results
Warsame et al. (2022)	Somalia	1990–2017	EFP, GDP, REC, POP, IQ, HC	ARDL, FMOLS; Granger causality	REC, IQ, HC decrease EFP; GDP, POP increase EFP	IQ→EFP
Wenlong et al. (2022)	10 Asian economies	1995–2018	GHG, EEF, TI, IQ, TO	CS-ARDL, AMG, CCEMG; Granger causality	EEF, TI decrease CO_2; TO and IQ increase CO2	Not investigated
Yang et al. (2022)	Developing Economies	1984–2016	CO_2, GDP, EC, GINI, IQ, IND, TO	Driscoll Kraay regression, FMOLS, PMG-ARDL; DHPC	GDP, EC, IND, IQ and TO increase CO_2; GINI, mixed CO_2	GDP, EC, IND, GINI and TO↔CO_2; IQ→CO2
Karimi Alavijeh et al. (2023)	EU countries	2000–2019	CO_2, GDP, REC, IQ, RD	MMQR, FMOLS, DOLS, FE	RD, IQ and REC decrease CO_2; GDP increase CO_2	Not investigated

→ is unidirectional causality, ↔ is bidirectional causality and ≠ is no causality relationships. EFP: Ecological footprint, CO_2: Carbon emissions, GHG: Greenhouse gas emission, GDP: Gross domestic product, FD: Financial development, TO: Trade openness, REC: Renewable energy consumption, TI: Technology innovation, ECO: eco-innovation, RD: Research and development expenditure, IQ: Institutional quality, POP: Population, HC: Human capital, EEF: Energy efficiency, GLO: Globalization, URB: Urbanization, GOV: Government consumption expenditure, EC: Energy consumption, GINI: Income inequality, IND: Industrialization, FID: Fiscal decentralization, FDI: Foreign direct investment, NREC: Non-renewable energy consumption

Author contributions Conceptualization: M.D., and C.I.; methodology: M.D., Software: M.D. investigation, writing—original draft preparation: M.D. and C.I. writing—review and editing, M.D., C.I. and S.O., Editing; R.A. and M.I., supervision, S.O. all authors have read and agreed to the published version of the manuscript.

Funding Not applicable.

Data availability The datasets generated and analyzed during the current study are available in the World Bank Indicator, http://data.worldbank.org

Declarations

Ethics approval and consent to participate Not applicable.

Consent for participate Not applicable.

Consent for publication Not applicable.

Conflicts of interest The authors declare no conflict of interest.

Competing interests The authors declare that they have no competing interests.

References

Ahmad M, Wu Y (2022) Household-based factors affecting uptake of biogas plants in Bangladesh: Implications for sustainable development. Renew Energy 194:858–867

Ahmad M et al (2021) Do inward foreign direct investment and economic development improve local environmental quality: aggregation bias puzzle. Environ Sci Pollut Res 28(26):34676–34696

Ahmad M, Ahmed Z, Yang X, Hussain N, Sinha A (2022a) Financial development and environmental degradation: do human capital and institutional quality make a difference? Gondwana Res 105:299–310. https://doi.org/10.1016/j.gr.2021.09.012

Ahmad M et al (2022b) Assessing long-and short-run dynamic interplay among balance of trade, aggregate economic output, real exchange rate, and CO2 emissions in Pakistan. Environ Dev Sustain 24(5):7283–7323

Ahmad M et al (2023) Households' perception-based factors influencing biogas adoption: Innovation diffusion framework. Energy 263:126155

Ahmad M, Jabeen G (2023) Relating economic openness and export diversification to eco-efficiency: Is green innovation critical? Int J Financ Econ. https://doi.org/10.1002/ijfe.2825

Ahmed F, Kousar S, Pervaiz A, Ramos-Requena JP (2020) Financial development, institutional quality, and environmental degradation nexus: New evidence from asymmetric ARDL co-integration approach. Sustainability 12(18):7812. https://doi.org/10.3390/su12187812

Altunöz U (2023) Analyzing the volatility spillover and cointegration relationship between daily spot West Texas intermediate crude oil price and US dollar. J Ekonomi 5(1):3–3. https://doi.org/10.58251/ekonomi.1255288

Alvarado R et al (2021) Ecological footprint, economic complexity and natural resources rents in Latin America: empirical evidence using quantile regressions. J Clean Prod 318:128585

Alvarado R et al (2022a) Biocapacity convergence clubs in Latin America: an analysis of their determining factors using quantile regressions. Environ Sci Pollut Res 29(44):66605–66621

Alvarado R et al (2022b) Impact of natural resources on economic progress: Evidence for trading blocs in Latin America using non-linear econometric methods. Resour Policy 79:102908

Alvarado R et al (2022c) Impact of the informal economy on the ecological footprint: The role of urban concentration and globalization. Econ Anal Policy 75:750–767

Anwar A, Chaudhary AR, Malik S, Bassim M (2021) Modelling the macroeconomic determinants of carbon dioxide emissions in the G-7 countries: the roles of technological innovation and institutional quality improvement. Glob Bus Rev. https://doi.org/10.1177/09721509211039392

Avci P, Sarıgül SS (2022) Is the performance of the companies operating in the participation index in the Turkish economy affected by the macroeconomic perspective? J Ekonomi 4(2):63–73. https://doi.org/10.58251/ekonomi.1182456

Azam M, Hunjra AI, Bouri E, Tan Y, Al-Faryan MAS (2021) Impact of institutional quality on sustainable development: Evidence from developing countries. J Environ Manag 298:113465

Bakhsh S, Yin H, Shabir M (2021) Foreign investment and CO2 emissions: do technological innovation and institutional quality matter? Evidence from system GMM approach. Environ Sci Pollut Res 28(15):19424–19438. https://doi.org/10.1007/s11356-020-12237-2

Baltagi BH, Feng Q, Kao C (2012) A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. J Econom 170(1):164–177. https://doi.org/10.1016/j.jeconom.2012.04.004

Belaid F, Dagher L, Filis G (2021) Revisiting the resource curse in the MENA region. Resour Policy 73:102225

Breusch TS, Pagan AR (1980) The Lagrange multiplier test and its applications to model specification in econometrics. Rev Econ Stud 47(1):239–253. https://doi.org/10.2307/2297111

Bulut U et al (2023) The nexus between government spending economic growth and tourism under climate change: testing the CEM model for the USA. Environ Sci Pollut Res 1–17. https://doi.org/10.1007/s11356-023-28319-w

Cao H, Khan MK, Rehman A, Dagar V, Oryani B, Tanveer A (2022) Impact of globalization, institutional quality, economic growth, electricity and renewable energy consumption on Carbon Dioxide Emission in OECD countries. Environ Sci Pollut Res 29(16):24191–24202

Çetin M et al (2023) The impact of natural resources, economic growth, savings, and current account balance on financial sector development: Theory and empirical evidence. Resour Policy 81:103300

Chhabra M, Giri AK, Kumar A (2023) Do trade openness and institutional quality contribute to carbon emission reduction? Evidence from BRICS countries. Environ Sci Pollut Res 30(17):50986–51002. https://doi.org/10.1007/s11356-023-25789-w

Chien F, Sadiq M, Li L, Sharif A (2023) The role of sustainable energy utility, natural resource utilization and waste management in reducing energy poverty: Evidence from South Asian countries. Util Policy 82:101581

Christoforidis T, Katrakilidis C (2021) The dynamic role of institutional quality, renewable and non-renewable energy on the ecological footprint of OECD countries: do institutions and renewables function as leverage points for environmental sustainability? Environ Sci Pollut Res 28(38):53888–53907

Chu LK (2022) The impact of informal economy on technological innovation–ecological footprint nexus in OECD countries: New evidence from panel quantile regression. J Environ Stud Sci 12(3):515–533. https://doi.org/10.1007/s13412-022-00756-y

Dagar V, Malik S (2023) Nexus between macroeconomic uncertainty, oil prices, and exports: evidence from quantile-on-quantile regression approach. Environ Sci Pollut Res 30(16):48363–48374

Dagher L (2012) Natural gas demand at the utility level: An application of dynamic elasticities. Energy Econ 34(4):961–969

Dagher L, Hasanov FJ (2023) Oil market shocks and financial instability in Asian countries. Int Rev Econ Financ 84:182–195

Dagher L, Fattouh B, Jamali I (2020) Oil price dynamics and energy transitions in the Middle East and North Africa: economic implications and structural reforms. Energy Policy 139:111329

Deng QS et al (2022) Asymmetric impacts of foreign direct investment inflows, financial development, and social globalization on environmental pollution. Econ Anal Policy 76:236–251. https://doi.org/10.1016/j.eap.2022.08.008

Dogru T et al (2019a) The balance of trade and exchange rates: Theory and contemporary evidence from tourism. Tour Manag 74:12–23

Dogru T et al (2020) The nexus between tourism, economic growth, renewable energy consumption, and carbon dioxide emissions: contemporary evidence from OECD countries. Environ Sci Pollut Res 27(32):40930–40948

Dogru T, et al (2023a) The impact of business models and state regulations on the accommodation sector: theory and empirical evidence from the recent pandemic. Int J Contem Hosp Manag

Dogru T et al (2023b) Employee turnover dynamics in the hospitality industry vs. the overall economy. Tour Manag 99:104783. https://doi.org/10.1016/j.tourman.2023.104783

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

Dzafic Z, Omerbašić A (2023) Circular economy in Bosnia and Herzegovina. J Ekonomi 5(1):35–39. https://doi.org/10.58251/ekonomi.1287906

Egbetokun S, Osabuohien E, Akinbobola T, Onanuga OT, Gershon O, Okafor V (2020) Environmental pollution, economic growth and institutional quality: exploring the nexus in Nigeria. Manag Environ Qual: An Int J 31(1):18–31. https://doi.org/10.1108/MEQ-02-2019-0050

Faroog et al (2023) The Nexus between Tourism-Energy-Environmental Degradation: Does Financial Development Matter in GCC countries? Tour Econ. https://doi.org/10.1177/13548166231174812

Fukuda-Parr S (2016) From the Millennium Development Goals to the Sustainable Development Goals: shifts in purpose, concept, and politics of global goal setting for development. Gend Dev 24(1):43–52

Global Footprint Network (2023) National Ecological Footprint and Biaocapacity Accounts, https://data.footprintnetwork.org, 2023. Accessed 23 March 2023

Habiba UMME, Xinbang C, Anwar A (2022) Do green technology innovations, financial development, and renewable energy use help to curb carbon emissions? Renew Energy 193:1082–1093. https://doi.org/10.1016/j.renene.2022.05.084

Hák T, Janoušková S, Moldan B (2016) Sustainable Development Goals: A need for relevant indicators. Ecol Ind 60:565–573. https://doi.org/10.1016/j.ecolind.2015.08.003

Haldar A, Sethi N (2021) Effect of institutional quality and renewable energy consumption on CO2 emissions− an empirical investigation for developing countries. Environ Sci Pollut Res 28(12):15485–15503. https://doi.org/10.1007/s11356-020-11532-2

Hussain M, Dogan E (2021) The role of institutional quality and environment-related technologies in environmental degradation for BRICS. J Clean Prod 304:127059. https://doi.org/10.1016/j.jclepro.2021.127059

IEA (2023) Shaping a secure and sustainable energy future for all. IEA, https://www.iea.org/news/committed-to-a-secure-and-sustainable-energy-future-for-all, 2021. Accessed 26 March 2023

Işık C (2010) Natural gas consumption and economic growth in Turkey: a bound test approach. Energy Systems 1(4):441–456. https://doi.org/10.1007/s12667-010-0018-1

Işık C (2013) The importance of creating a competitive advantage and investing in information technology for modern economies: an

ARDL test approach from Turkey. J Knowl Econ 4(4):387–405. https://doi.org/10.1007/s13132-011-0075-2
Işık C, Radulescu M (2017) Investigation of the relationship between renewable energy, tourism receipts and economic growth in Europe. Statistika-Statistics and Economy Journal 97(2):85–94
Işık C, Kasımatı E, Ongan S (2017) Analyzing the causalities between economic growth financial development international trade tourism expenditure and/on the CO2emissions in Greece. Energy Sources Part B: Economics Planning and Policy 12(7):665–673. https://doi.org/10.1080/15567249.2016.1263251
Işık C, Dogru T, Sirakaya-Turk E (2018) A nexus of linear and nonlinear relationships between tourism demand renewable energy consumption and economic growth: theory and evidence. Int J Tour Res 20(1):38–49. https://doi.org/10.1002/jtr.2151
Işık C, Ongan S, Özdemir D (2019a) The economic growth/development and environmental degradation: evidence from the US state-level EKC hypothesis. Environ Sci Pollut Res 26(30):30772–30781. https://doi.org/10.1007/s11356-019-06276-7
Işık C, Ongan S, Özdemir D (2019b) Testing the EKC hypothesis for ten US states: an application of heterogeneous panel estimation method. Environ Sci Pollut Res 26(11):10846–10853. https://doi.org/10.1007/s11356-019-04514-6
Işık C, Ahmad M, Pata UK, Ongan S, Radulescu M, Adedoyin FF, Ongan, A, (2020) An evaluation of the tourism-induced environmental Kuznets curve (T-EKC) hypothesis: evidence from G7 Countries. Sustainability 12(21):9150. https://doi.org/10.3390/su12219150
Işık C, Sirakaya-Turk E, Ongan S (2020b) Testing the efficacy of the economic policy uncertainty index on tourism demand in USMCA: Theory and evidence. Tourism Economics 26(8):1344–1357.
Işık C, Ongan S, Ozdemir D, Ahmad M, Irfan M, Alvarado R, Ongan A (2021a) The increases and decreases of the environment Kuznets curve (EKC) for 8 OECD countries. Environ Sci Pollut Res 28(22):28535–28543
Işık C, Ahmad M, Ongan S, Ozdemir D, Irfan M, Alvarado R (2021b) Convergence analysis of the ecological footprint: theory and empirical evidence from the USMCA countries. Environ Sci Pollut Res 28(25):32648–32659
Işık C, Ongan S, Bulut U, Karakaya S, Irfan M, Alvarado R, Rehman A (2022) Reinvestigating the Environmental Kuznets Curve (EKC) hypothesis by a composite model constructed on the Armey curve hypothesis with government spending for the US States. Environ Sci Pollut Res 29(11):16472–16483. https://doi.org/10.1007/s11356-021-16720-2
Işık C, Simionescu M, Ongan S, Radulescu M, Yousaf Z, Rehman A, Ahmad M (2023) Renewable energy, economic freedom and economic policy uncertainty: New evidence from a dynamic panel threshold analysis for the G-7 and BRIC countries. Stoch Environ Res Risk Assess 1–16. https://doi.org/10.1007/s00477-023-02452-x
Islam MM, Khan MK, Tareque M, Jehan N, Dagar V (2021) Impact of globalization, foreign direct investment, and energy consumption on CO2 emissions in Bangladesh: Does institutional quality matter? Environ Sci Pollut Res 28(35):48851–48871. https://doi.org/10.1007/s11356-021-13441-4
Islam H, Rahman J, Tanchangya T, Islam MA (2023) Impact of firms' size, leverage, and net profit margin on firms' profitability in the manufacturing sector of Bangladesh: An empirical analysis using GMM estimation. J Ekonomi 5(1):1–9. https://doi.org/10.58251/ekonomi.1275742
Jabeen G et al (2023) Role of energy utilization intensity, technical development, economic openness, and foreign tourism in environmental sustainability. Gondw Res. https://doi.org/10.1016/j.gr.2023.03.001
Jiang Y, Sharif A, Anwar A, Cong PT, Lelchumanan B, Yen VT, Vinh NTT (2023). Does green growth in E-7 countries depend on economic policy uncertainty, institutional quality, and renewable energy? Evidence from quantile-based regression. Geosci Front. https://doi.org/10.1016/j.gsf.2023.101652
Jianguo D, Ali K, Alnori F, Ullah S (2022) The nexus of financial development, technological innovation, institutional quality, and environmental quality: Evidence from OECD economies. Environ Sci Pollut Res 29(38):58179–58200. https://doi.org/10.1007/s11356-022-19763-1
Jie H et al (2023) The construction of green finance and high-quality economic development under China's SDGs target. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-023-28977-w
Karimi Alavijeh N, Ahmadi Shadmehri MT, Nazeer N, Zangoei S, Dehdar F (2023) The role of renewable energy consumption on environmental degradation in EU countries: do institutional quality, technological innovation, and GDP matter? Environ Sci Pollut Res 30(15):44607–44624. https://doi.org/10.1007/s11356-023-25428-4
Khan H, Weili L, Khan I (2021) Recent advances in energy usage and environmental degradation: Does quality institutions matter? A worldwide evidence. Energy Rep 7:1091–1103. https://doi.org/10.1016/j.egyr.2021.01.085
Kirikkaleli D, Sofuoğlu E, Ojekemi O (2023) Does patents on environmental technologies matter for the ecological footprint in the USA? Evidence from the novel Fourier ARDL approach. Geosci Front 14(4):101564. https://doi.org/10.1016/j.gsf.2023.101564
Kumar S, Kumar N, Vivekadhish S (2016) Millennium development goals (MDGS) to sustainable development goals (SDGS): Addressing unfinished agenda and strengthening sustainable development and partnership. Indian J Community Med: Official Publication of Indian Association of Preventive & Social Medicine 41(1):1
Le HP, Ozturk I (2020) The impacts of globalization, financial development, government expenditures, and institutional quality on CO 2 emissions in the presence of environmental Kuznets curve. Environ Sci Pollut Res 27:22680–22697. https://doi.org/10.1007/s11356-020-08812-2
Liu H, Anwar A, Razzaq A, Yang L (2022) The key role of renewable energy consumption, technological innovation and institutional quality in formulating the SDG policies for emerging economies: Evidence from quantile regression. Energy Rep 8:11810–11824. https://doi.org/10.1016/j.egyr.2022.08.231
Narayan PK, Narayan S (2010) Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy Policy 38(1):661–666. https://doi.org/10.1016/j.enpol.2009.09.005
Ni Z, Yang J, Razzaq A (2022) How do natural resources, digitalization, and institutional governance contribute to ecological sustainability through load capacity factors in highly resource-consuming economies? Res Policy 79:103068. https://doi.org/10.1016/j.resourpol.2022.103068
Obobisa ES, Chen H, Mensah IA (2022) The impact of green technological innovation and institutional quality on CO2 emissions in African countries. Technol Forecast Soc Chang 180:121670. https://doi.org/10.1016/j.techfore.2022.121670
Ongan S et al (2021) Economic growth and environmental degradation: evidence from the US case environmental Kuznets curve hypothesis with application of decomposition. J Environ Econ Policy 10(1):14–21
Ongan S et al (2023) Are economic growth and environmental pollution dilemma? Environ Sci Pollut Res 30(17):49591–49604
Ongan S et al (2022) Retesting the EKC hypothesis through transmission of the ARMEY curve model: an alternative composite model approach with theory and policy implications for NAFTA countries. Environ Sci Pollut Res 1–13. https://doi.org/10.1007/s11356-022-19106-0

Ozturk I, Acaravci A (2010) CO2 emissions, energy consumption and economic growth in Turkey. Renew Sustain Energy Rev 14(9):3220–3225. https://doi.org/10.1016/j.rser.2010.07.005
Pao HT, Tsai CM (2010) CO2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38(12):7850–7860. https://doi.org/10.1016/j.enpol.2010.08.045
Pata UK, Isik C (2021) Determinants of the load capacity factor in China: a novel dynamic ARDL approach for ecological footprint accounting. Resour Policy 74:102313
Pata UK, Kartal MT, Dam MM, Kaya F (2023a) Navigating the Impact of Renewable Energy, Trade Openness, Income, and Globalization on Load Capacity Factor: The Case of Latin American and Caribbean (LAC) Countries. Int J Energy Res. https://doi.org/10.1155/2023/6828781
Pata UK, Dam MM, Kaya F (2023b) How effective are renewable energy, tourism, trade openness, and foreign direct investment on CO2 emissions? An EKC analysis for ASEAN countries. Environ Sci Pollut Res 30(6):14821–14837. https://doi.org/10.1007/s11356-022-23160-z
Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Economet 22(2):265–312. https://doi.org/10.1002/jae.951
Pesaran MH (2021) General diagnostic tests for cross-sectional dependence in panels. Empir Econ 60(1):13–50. https://doi.org/10.1007/s00181-020-01875-7
Pesaran MH, Yamagata T (2008) Testing slope homogeneity in large panels. J Econom 142(1):50–93. https://doi.org/10.1016/j.jeconom.2007.05.010
Pesaran MH, Shin Y, Smith RP (1999) Pooled mean group estimation of dynamic heterogeneous panels. J Am Stat Assoc 94(446):621–634. https://doi.org/10.1080/01621459.1999.10474156
Piwowar-Sulej K, Malik S, Shobande OA, Singh S, Dagar V (2023) A contribution to sustainable human resource development in the era of the COVID-19 Pandemic. J Bus Ethics 1–19. https://doi.org/10.1007/s10551-023-05456-3
Rao A, Dagar V, Sohag K, Dagher L, Tanin TI (2023) Good for the planet, good for the wallet: the ESG impact on financial performance in India. Finance Res Lett 104093. https://doi.org/10.1016/j.frl.2023.104093
Razzaq A, Sharif A, Ozturk I, Afshan S (2023) Dynamic and threshold effects of energy transition and environmental governance on green growth in COP26 framework. Renew Sustain Energy Rev 179:113296
Rehman A et al (2021a) Carbonization and atmospheric pollution in China: The asymmetric impacts of forests, livestock production, and economic progress on CO2 emissions. J Environ Manag 294:113059
Rehman A, Ma H, Ozturk I, Murshed M, Dagar V (2021b) The dynamic impacts of CO2 emissions from different sources on Pakistan's economic progress: a roadmap to sustainable development. Environ Dev Sustain 23(12):17857–17880
Rehman A et al (2022) Carbonization and agricultural productivity in Bhutan: Investigating the impact of crops production, fertilizer usage, and employment on CO2 emissions. J Clean Prod 375:134178
Rehman A et al (2023) Globalization and renewable energy use: how are they contributing to upsurge the CO2 emissions? A global perspective. Environ Sci Pollut Res 30(4):9699–9712
Sachs JD (2012) From millennium development goals to sustainable development goals. Lancet 379(9832):2206–2211
Sachs JD, McArthur JW (2005) The millennium project: a plan for meeting the millennium development goals. Lancet 365(9456):347–353
Safi A, Chen Y, Zheng L (2022) The Impact of Energy Productivity and Eco-Innovation on Sustainable Environment in Emerging Seven (E-7) Countries: Does Institutional Quality Matter?. Front Public Health 10. https://doi.org/10.3389/fpubh.2022.878243
Shang Y, Razzaq A, Chupradit S, An NB, Abdul-Samad Z (2022) The role of renewable energy consumption and health expenditures in improving load capacity factor in ASEAN countries: exploring new paradigm using advance panel models. Renew Energy 191:715–722. https://doi.org/10.1016/j.renene.2022.04.013
Sharif A, Saqib N, Dong K, Khan SAR (2022) Nexus between green technology innovation, green financing, and CO2 emissions in the G7 countries: the moderating role of social globalisation. Sustain Dev 30(6):1934–1946
Sharif A, Mehmood U, Tiwari S (2023) A step towards sustainable development: role of green energy and environmental innovation. Environ Dev Sustain 1–22. https://doi.org/10.1007/s10668-023-03111-5
Siche R, Pereira L, Agostinho F, Ortega E (2010) Convergence of ecological footprint and emergy analysis as a sustainability indicator of countries: Peru as case study. Commun Nonlinear Sci Numer Simul 15(10):3182–3192
Udeagha MC, Ngepah N (2022) Dynamic ARDL simulations effects of fiscal decentralization, green technological innovation, trade openness, and institutional quality on environmental sustainability: evidence from South Africa. Sustainability 14(16):10268. https://doi.org/10.3390/su141610268
Wahab S, Imran M, Safi A, Wahab Z, Kirikkaleli D (2022) Role of financial stability, technological innovation, and renewable energy in achieving sustainable development goals in BRICS countries. Environ Sci Pollut Res 29(32):48827–48838
Warsame AA, Sheik-Ali IA, Mohamed J, Sarkodie SA (2022) Renewables and institutional quality mitigate environmental degradation in Somalia. Renew Energy 194:1184–1191. https://doi.org/10.1016/j.renene.2022.05.109
WDI (2023) World development indicators. https://datacatalog.worldbank.org/search/dataset/0037712/World-Development-Indicators, 2023. Accessed 26 March 2023
Wenlong Z, Tien NH, Sibghatullah A, Asih D, Soelton M, Ramli Y (2022) Impact of energy efficiency, technology innovation, institutional quality, and trade openness on greenhouse gas emissions in ten Asian economies. Environ Sci Pollut Res 1–16. https://doi.org/10.1007/s11356-022-20079-3
WGI (2023) Worldwide Governance Indicators. https://info.worldbank.org/governance/wgi/. Accessed 13 March 2023
Yang B, Ali M, Hashmi SH, Jahanger A (2022) Do income inequality and institutional quality affect CO2 emissions in developing economies? Environ Sci Pollut Res 29(28):42720–42741. https://doi.org/10.1007/s11356-021-18278-5