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ECONOMIC UNCERTAINTY, (GEO)POLITICAL RISK, AND SUSTAINABLE DEVELOPMENT GOALS

A different look at the environmental Kuznets curve from the perspective of environmental deterioration and economic policy uncertainty: evidence from fragile countries

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Abstract
Environmental degradation is one of the most significant issues that developing nations confront and needs to be resolved right away in order for them to achieve sustainable development. Government policies are crucial in this situation since emerging nations frequently struggle with the issue of policy ambiguity, which can result in environmental deterioration. In this context, this study investigates how policy uncertainty affects environmental degradation in the five fragile emerging economies known as the Fragile Five—Brazil, India, Indonesia, South Africa, and Turkey. Using data from 1996 to 2019, we estimate a Panel Quantile Regression analysis. The empirical findings indicate that economic policy uncertainty and technology innovation increases the environmental degradation whereas environmental degradation is slowed down by financial development and renewable energy consumption. Empirical evidence also confirms the presence of EKC hypothesis in fragile economies. Based on the findings, we suggest both a policy and an environmental framework for achieving sustainable development in fragile economies.

Keywords Economic policy uncertainty · Environmental degradation index · Panel quantile regression · Fragile countries

Introduction

In terms of achieving sustainable development, developing economies are still facing many issues. Environmental degradation is one of the major issues experienced by these

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countries and must be resolved by reducing carbon dioxide (CO_2) emissions on a worldwide scale. If not, the trend of increasing CO_2 emissions might be more troublesome (IPCC, 2018). As a result, there has been an uptick in recent years in the conversation concerning environmental degradation, climate change, and global warming. One of the effects of energy generation is environmental deterioration (Mukhtarov 2022). Given that there is a high demand for energy and a limited supply (Mutezo and Mulopo 2021), environmental deterioration accelerates as a result of the use of fossil fuels, which results in CO2 emissions, which have the highest rate of all greenhouse gas emissions (Depren et al. 2022). Olivier et al. (2012) show that industrialized nations contribute significantly to environmental deterioration on a worldwide scale. At the same time, this scenario is changing, with emerging countries like the fragile five economies beginning to contribute more to environmental degradation.

The literature discusses various factors that contribute to environmental degradation, including renewable energy (RE), technological innovation (Wen et al. 2021; Wen et al. 2022; Wang et al. 2022; Kirikkaleli et al. 2022), and economic policy uncertainty (EPU) (Candau and Dienesch 2017; Masron and Subramaniam 2018; Su et al. 2021; Sekraf and Sghaier 2018; Adebayo et al. 2022a, b and c). EPU can be attributed to factors such as the COVID-19 pandemic, the US-China trade war, the financial crisis, and Brexit, which result in ambiguous economic policies. The International Monetary Fund (IMF) identifies EPU as a cause of environmental destruction and slow economic expansion. This is because EPU reduces energy consumption and economic growth, leading to an increase in environmental degradation. Additionally, EPU can hinder R&D, technological innovation, and the development of RE sources, further contributing to environmental degradation (Anser et al. 2021). Corruption in the government can also undermine effective direction and control to confirm ecological sustainability, as highlighted by Biswas et al. (2012) and Sekraf and Sghaier (2018). Conversely, political stability may prevent environmental degradation by adopting effective policies, which in turn can help reduce waste and pollution and safeguard the environment (Helland and Whitford 2003). Therefore, the link between EPU and environmental degradation is a topic of debate, and it is essential to determine the link between the two (Vu and Huang 2020) to recommend policies to combat environmental degradation (Farooq et al. 2021).

Over the past few decades, economic expansion has had a negative effect on both the environment and the quality of life (Charfeddine and Mrabet 2017; Canaj et al. 2021). The exploitation of natural resources resulting from economic activities is one of the leading causes of environmental degradation (Cronin and Pandya 2009; Gutti et al. 2012). Alvarado and Toledo (2017) suggest that there is a negative correlation between real gross domestic product (GDP) income and environmental degradation. The EKC is a theoretical and empirical concept that claims that environmental degradation primarily rises during the early phases of economic growth but subsequently declines as incomes rise (Stern et al. 1996; Stern 2004). The EKC is based on an inverted U-shape, which suggests that higher levels of production during the initial stages of economic development lead to more environmental degradation, but as a country develops, technology improves, efficiency increases, and the population becomes more concerned with the environment, environmental degradation begins to decline (Stern 2004).

The influence of technological innovation on CO_2 emissions is a topic of ongoing debate, but according to new growth theories, technological innovation has a direct positive impact on both economic expansion and the environment (Xinmin et al. 2020). While technological innovation is crucial for the development of economies and firms, it heavily relies on energy use, which can lead to environmental pollution (Omri et al., 2020). However, Asongu et al. (2018) argue that technological innovation can also serve as a tool for improving environmental quality by reducing CO_2 emissions. This suggests that while technological innovation has the potential to contribute to environmental degradation, it can also be used to mitigate the negative impact of economic expansion on the environment.

Financial development is a factor that may have an impact on environmental degradation. Some studies, such as that of Islam et al. (2013), indicate that financial development can reduce environmental degradation by promoting energy efficiency. On the other hand, Dogan and Kurkekul (2016) discuss how financial development can increase investments in equipment and lead to more energy consumption and CO_2 emissions. As a result, there is no consensus on the link between financial development and environmental degradation, and it can have positive, negative, or neutral effects (Ahmad et al. 2023). RE consumption and production are now generally considered significant factors for the environment and the growth of the economy (Raza et al. 2019). In addition, policymakers need to understand the connection between environmental degradation and RE consumption to plan the path of economic growth (Adebayo and Kirikkaleli 2021), since RE consumption can be seen as a significant factor in the environment and growth (Ocal and Aslan 2013a, Raza et al. 2015). Krewitt et al. (2007), Guoyan et al. (2022), Abulfotuh (2007), Chien and Hu (2008), Raza et al. (2022), and Raza and Shah (2018) advocate RE usage, which supports a decrease in emissions of greenhouse gases, air population, total energy consumption, and economic growth (Dai et al. 2016). Studies like that of Dong et al. (2018) suggest that increasing RE consumption and reducing reliance on fossil fuels can help reduce environmental degradation. Furthermore, RE consumption can contribute to economic development without significantly increasing environmental degradation (Mehmood et al. 2023). Therefore, policymakers aim to reduce the use of fossil fuels and increase the use of RE sources to combat environmental pollution (Sharif et al. 2020).

The main challenges faced by developing countries, particularly those identified as the "fragile five"—Turkey, South Africa, Brazil, Indonesia, and India —include sustainable economic growth, climate change, health issues, and the use of clean energy resources (Barut et al. 2023). These countries are experiencing environmental degradation, accounting for 9.22% of global degradation (Gao et al. 2022). These fragile economies also suffer from high inflation, large current account deficits, fast capital outflows, and weak economic growth. Given these economic and environmental factors, it is likely that the fragile five economies will continue to be susceptible to environmental degradation (Unver and Dogru, 2015).

Table 1 summarizes the regional CO_2 emissions for the world. According to Table 1, there is a decrease in CO_2 emissions in North America, South and Central America, and Europe. On the other hand, in the rest of the world, which includes the Commonwealth of Independent States, the Middle East, Africa, and Asia Pacific, there is an increase in CO_2 emissions. Also, Table 1 indicates that the CO_2 emissions for Indonesia, Turkey, and India are high when compared to other regions and fragile countries, and that, except for South Africa, the rest of the fragile economies, which are Argentina and Brazil, do not have low CO_2 emissions.

In this context, the current paper explores the impact of GDP, EPU, financial development (FD), RENE and technological innovation (TIN) on environmental degradation for the period 1996–2019 using data from five fragile countries (Brazil, India, Indonesia, Turkey and South Africa). For this purpose, firstly, the environmental degradation index is measured with various environmental variables using principal component analysis (PCA), and then panel quantitative regression analysis is used to determine the relationship between the effects of GDP, EPU, FD, RENE. In this context, the study seeks answers to the following research questions: *"Is there a connection between the variables selected in the study (GDP, FD, TIN, RENE) and environmental degradation? If yes, what is the nature of this relationship?"*, and "*Is the EKC hypothesis valid for Five Fragile countries?"*.

Answers to these research questions are sought in this study, which is anticipated to make numerous contributions to the literature. Firstly, the present study is a pioneering attempt to investigate the impact of economic policy uncertainty, technological innovation, RE consumption, and financial development on environmental degradation under the EKC framework for fragile countries (Turkey, South Africa, Brazil, Indonesia, and India). In the previous studies, the link between variables such as RENE, EPU, FD, and environmental degradation was separately discussed; however, the combined role of RENE, GDP, FD, TIN, and EPU on environmental degradation was not widely discussed. This study examines the effects of RENE, GDP, FD, TIN, and EPU variables in the same model. Secondly, the existing literature has used CO_2 emissions or ecological footprints as a measure of environmental degradation, whereas this study calculates and uses a comprehensive index of environmental degradation by incorporating different environmental indicators by following the method of Barut et al. (2023). Thirdly, most of the time, the macroeconomic variables have the issue of data non-normality. Therefore, in cases of data non-normality, the use of linear average-based econometric techniques may provide inconclusive and spurious outcomes; therefore, this study uses panel quantile regression to control the issue of data non-normality and address the impact of outliers. The current study focuses on quantile regression analysis, unlike the previous studies. A lot of the studies on the relationship between energy consumption and CO2 emissions include the top 10 emitting countries (Nejat et al. 2015), China (Bai et al. 2019), Brazil (Gioda 2019), low and lower middle income, upper middle income, and

Table 1 Growth Rate of CO_2 Emissions in Different Regions and Countries of the World

CO_2 Emissions	2011	2021	Growth rate per annum from 2011 to 2021	CO_2 Emissions	2011	2021	Growth rate per annum from 2011 to 2021
Total North America	6352.2	5602.2	-1.2%	Argentina	173.1	181.7	0.5%
Total South & Central America	1225.1	1213.1	-0.1%	Brazil	424.2	436.6	0.3%
Total Europe	4599.1	3793.7	-1.9%	Turkey	298.8	403.3	3.0%
Total Commonwealth of Independent States	2046.5	2132.5	0.4%	South Africa	466.3	438.9	-0.6%
Total Middle East	1764.5	2117.2	1.8%	India	1728.4	2552.8	4.0%
Total Africa	1103.6	1290.7	1.6%	Indonesia	470.6	572.5	2.0%
Total Asia Pacific	14,813.5	17,734.6	1.8%	Total World	31,904.6	33,884.1	0.6%

Source: BP Energy Outlook (2022)

high-income countries (Narayan and Doytch 2017), BRICS, and N-11 countries (Raza et al. 2020a, b). However, there is no study on the fragile five economies to determine the effect of economic policy uncertainty, technological innovation, RE consumption, and financial development on environmental degradation. The final contribution of this study is focusing on the fragile five countries, which have high EPU. Thus, the findings of this study may shed light on recommendations for policymakers since the nexus between natural resources, economic expansion, and environmental degradation is not only beneficial for government and policymakers but also important for the growth of RE. The findings of this study not only support ensuring the Sustainable Development Goals, which contain decreasing green gas emissions by 2050, but also help reach the goal of a robust and sustainable economy as expressed by Zhang et al. (2023).

The current paper consists of five parts. The second part gives information about the literature summary, and the third part introduces data and techniques. Also, the findings are given in the fourth part, and the conclusion is in the final part.

Literature review

It is important to see that the literature on the link between economic expansion and environmental degradation has many diverse and contradictory conclusions. While Wang et al. (2022a, b), Boukhelkhal (2022), Al-mulali et al. (2013), Wang et al. (2012), Wang et al. (2013), Elif et al. (2011), Acaravcı and Ozturk (2010) discovered that economic growth increases environmental degradation, studies such as Salazar-Nunez et al. (2022), Adebanjo and Shakiru (2022), Weimin et al. (2022), Heidari et al. (2015), Narayan and Pop (2012), and Jaunky (2010) have identified that economic expansion reduces environmental degradation in the long term. The EKC model, which states that the CO2 emissions curve in the graph rises until it reaches a specific income level, at which time it turns downward and forms an inverted "U" curve, clarifies this ambiguity (Arouri et al. 2012). In other words, despite a short-term increase, long-term CO2 emissions decrease as income increases. Using historical, relatively short-term data series and environmental quality measures that can be acknowledged as sub-par, it is possible to test the possibility of an EKC (Chen and Taylor 2020).

According to the literature review, studies such as Raza et al. (2020a, b), and Suki et al. (2020) support the EKC hypothesis. However, studies such Erdogan et al. (2020) did not reach the results predicted by the EKC hypothesis. Murshed et al. (2022), and Gormus and Aydin (2020) found that while the EKC is valid for several countries, it is invalid for others. Furthermore, Ansari (2022) concluded that the EKC hypothesis is valid for ecological footprints but invalid for CO_2 emissions. Conversely, Dogan et al. (2020) showed that the EKC hypothesis for ecological footprints is invalid.

Environmental degradation is affected by many factors besides economic growth. The following studies on the independent factors impacting environmental deterioration are some of those cited in this study. For example, Anser et al. (2021), and Adedoyin and Zakari (2020) indicate that while the link between uncertainty in economic policies and environmental degradation is optimistic in the short term, it is adverse in the long term. On the contrary, Syed and Bouri (2022) concluded that while uncertainty in economic policies negatively affects environmental degradation in the short run, it has a positive effect in the long run. Abbasi and Adedoyin (2021), on the other hand, found a significant difference between the two variables, Mukhtarov et al. (2023), Adebayo et al. (2022b), Khan et al. (2022), Kirikkaleli et al. (2022), Khan et al. (2020a, b), Wolde-Rufael and Weldemeskel (2020), Zafar et al. (2020) discovered that there is a negative link between RE usage and environmental degradation.

Khan and Ozturk (2021), Zhao and Yang (2020), and Rafique (2020) found that environmental degradation and financial development are mutually contradictory. In contrast, Anwar et al. (2021a, b, c, d), Le and Ozturk (2020), and Qayyum et al. (2021) discovered a positive link between financial development and environmental degradation. Along with identifying a link between financial development and environmental degradation, Lv and Li (2021) also made the remarkable finding that the financial development levels of its neighbors influence a country's CO_2 emissions, which decline as the financial development levels of its neighbors rise. Shahbaz et al. (2020), and Cheng et al. (2021) assert that there is a negative link between technological innovation and environmental degradation. In contrast, Adebayo et al. (2021) find that environmental deterioration and technological progress are positively correlated. Raza et al. (2019) support the positive effect of economic growth and transportation energy consumption on environmental degradation in the US. Zhang et al. (2023) research globalization, EPU, ecological innovation, and RENE in the 1990–2019 period and assert that EPU and RENE decrease CO2, and ecological innovation supports reducing CO2 emissions. Kirikkaleli et al. (2023) study the relationship between GDP, globalization, and the carbon intensity of GDP on consumption-based CO2 emissions (CO2E) by using the nonlinear autoregressive distributed lag bound test (ARDL) and Fourier ARDL and claim that there is a significant long-run relationship between variables. Also, the findings prove that positive environmental innovations have a negative effect on the CO2E, positive and negative shocks in GDP and carbon intensity of GDP have a positive effect on the CO2E, and a negative shock in globalization increases the CCO2E. Ramzan et al. (2023) explore the effect of financial depth, information communication technology, technological innovation, and green innovation on CO2 emissions and ecological footprint in the 1980–2019 period for the 10 greenest economies by using the Method of Moments Quantile Regression (MMQR) and causality test. The findings of Ramzan et al. (2023) demonstrate that green innovation and financial depth significantly decrease CO2 emissions and ecological footprints, but information communication technology increases CO2 emissions and ecological footprint.

Data, model specifications, and methodology

Data

The current paper aims to measure environmental degradation in five countries, namely Turkey, South Africa, Brazil, Indonesia, and India, using an environmental degradation index proposed by Barut et al. (2023). This study studies the five fragile economies. The CO2 emission for fragile countries, particularly Indonesia, Turkey, and India, is high when compared to other regions in the world, according to the BP Energy Outlook Report (2022), which is given in Table 1. Also, these countries are experiencing environmental degradation, accounting for 9.22% of global degradation (Gao et al. 2022), and suffer from high inflation, large current account deficits, fast capital outflows, and weak economic growth. Due to the availability of data, this study spans the years 1996 through 2019. For the vulnerable five economies in particular, earlier environmental data are not available.

The environmental degradation index takes into account various environmental dimensions, and the study covers comprehensive indicators to measure environmental degradation since there is no consensus on how to measure it in the literature (Nyugen, 2020). To construct the environmental degradation index, the study uses several variables, such as usage of coal per inhabited area, CO_2 emissions per GDP, vehicle GDP per capita, nitrous oxide, and methane emissions, fertilizer use per hectare of arable land, population density, CO_2 emissions per person, number of threatened birds, and number of threatened mammals. These variables are in line with the studies of Anwar and Malik (2021), Anwar et al. (2023), Sun et al. (2023), Anwar et al. (2021, 2021a, 2021b), Anwar et al. (2022), Esmaeili et al. (2023), Liu et al. (2022), Habiba et al. (2022), Salem et al. (2021), Cai et al. (2022), Chien et al. (2021), and Farooq et al. (2021),. The environmental deterioration index is created by the study using principal component analysis (PCA), as suggested by Jha and Murthy (2003). PCA is a standard analysis for simplifying data (Le et al. 2019) and is widely employed in the literature (Jolliffe 2011). The advantages of PCA are low noise sensitivity, decreased requirements for capacity and memory, and increased efficiency in smaller dimensions (Karamizadeh et al. 2013). Thus, this study uses PCA analysis to measure environmental degradation. Before running the PCA, all variables are standardized, following the suggestion of Le et al. (2019). The PCA gives the weight of the environmental degradation index, which is presented in Table 2. Finally, the environmental degradation index is constructed using the weights. Table 2 indicates that the first two modules clarify 79% of the total variance of the environmental degradation index. Furthermore, the Kaiser–Meyer–Olkin analysis reports that the model is sufficient, and Bartlett's analysis indicates that the variables are related to each other for PCA. Finally, the values of the environmental degradation index differ between 0, in which the environmental degradation level is low, and 100, in which the environmental degradation level is high.

This study investigates the influence of GDP, EPU, FD, RENE, FD, and Tin using data from five fragile nations (Brazil, India, Indonesia, Turkey, and South Africa) between 1996 and 2019. The selection of data period is based on the availability of the data, as the data of few variables of the study is not available before the year 1996. The authors created EDI, which is the dependent variable of the paper, by combining ten different variables. Information about GDP, EPU, RENE, FD, and TIN data are given in Table 3, and a graphical presentation is given in sub-sections (a, b, c, d, and e) of Fig. 1.

GDP per capita (GDP) is the first independent variable in the study because it impacts energy consumption, which

Table 2 PCA findings for measuring environmental degradation index

Total Variance for Components			
Components	Eigen Values	% of Variance	Cumulative Variance
1	6.14	0.68	0.68
2	0.99	0.11	0.79
3	0.66	0.07	0.87
4	0.47	0.05	0.92
5	0.34	0.04	0.96
6	0.26	0.03	0.98
7	0.08	0.01	0.99
8	0.06	0.01	0.99
9	0.03	0.00	1

Table 3 Description of data

Sign	Variables	Proxy	Data Source
EDI	Environmental Degradation Index	%	Created by the authors
GDP	GDP per capita	Current US$	WDI-2023
EPU	Economic Policy Uncertainty	World uncertainty Index	https://worlduncertaintyindex.com/
TIN	Technological Innovation	Patent applications residents + non-residents	WDI-2023
FD	Financial Development	Domestic credit to private sector (% of GDP)	WDI-2023
RENE	RE Consumption	% of total final energy consumption	WDI-2023

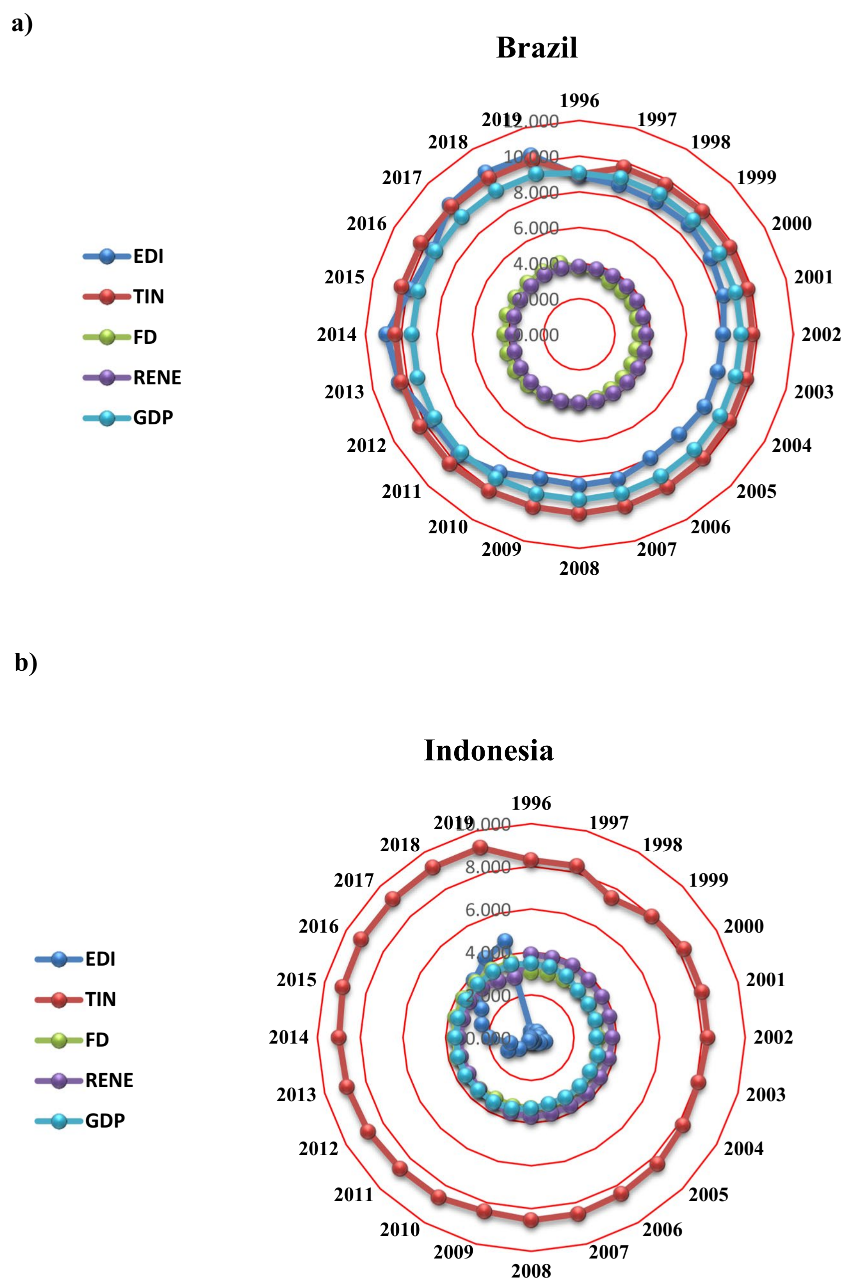
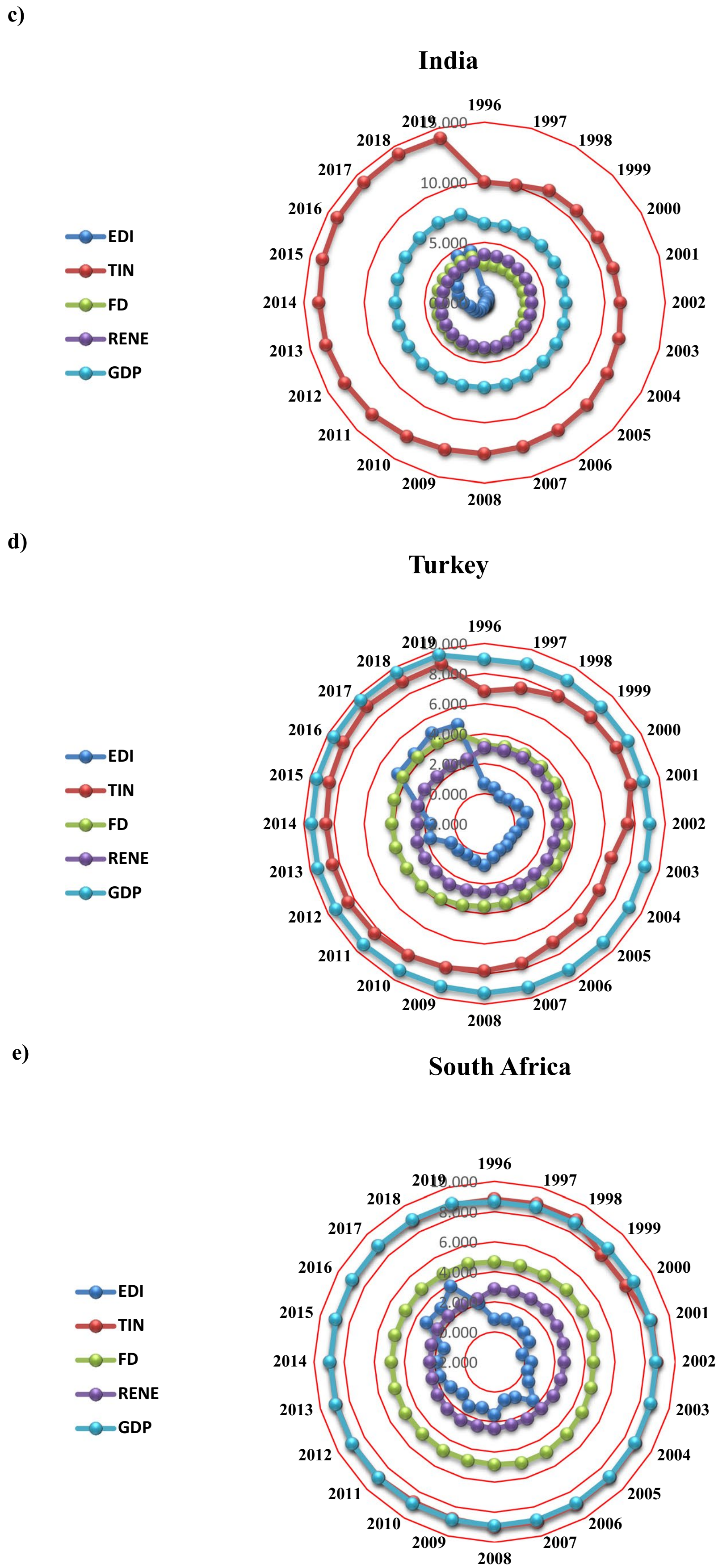


Fig. 1 Data trends of fragile five economies

Fig. 1 (continued)



in turn affects environmental degradation by creating CO2 emissions (Zafar et al. 2020). The study's other independent variable, financial development, was chosen since it is presumable that it can both raise investments in clean energy and green technologies while also reducing environmental deterioration. On the other hand, Zafar et al. (2020) assert that financial development can both boost economic activity and worsen the environment. As a result, it has been decided that the financial development variable (FD) is the most relevant in terms of environmental deterioration. Technology has significant effects on economic growth and environmental degradation.

Model specification

The non-linear link between environmental indices (like air pollution) and welfare measurements (like income per capita) is typically modelled using a quadratic equation in traditional testing for the EKC hypothesis (Wang 2013). Thus, the quadratic functional form is estimated using the methods in the study, which excludes cubic functional form. Kuznets (1955), using the income distribution data of two states in America, England, and Germany, estimated how income inequality will move in the economic growth process with Eq. (1).

$$\text{GINI} = f\left(\text{GDPPER}, \text{GDPPER}^2\right) \tag{1}$$

In Eq. (1), GINI represents income inequality, and GDPPER represents GDP per capita. GDPPER^2 is the square form of GDP per capita. According to Kuznets (1955), income inequality increases at first, but later on, with industrialization (Fig. 2), individuals' incomes will increase and income inequality will decrease.

Following Eq. (1), Grossman and Krueger (1991) developed Eq. (2) by adapting the Kuznets Curve to the environment (Fig. 3).

$$CO_2 = \left(\text{GDPPER}, \text{GDPPER}^2\right) \tag{2}$$

Equation (2) states that countries choosing a more aggressive growth strategy during the early phases of industrialization disregard the environment, which results in an increase in CO_2 emissions. However, it has been stated that in the following periods, with the increase in industrialization and the increase in the income of individuals, their sensitivity to the environment will increase, which will lead to a decrease in CO_2 emissions.

In this study, Eq. (3) was established by following the studies of Citil et al. (2023) and Liu and Zhang (2023).

$$\mathbf{EDI - GDP + GDP^2 + EPU + RENE + FC + TIN} \tag{3}$$

In Eq. (3), the dependent variable is the Environmental Degradation Index (EDI), and the independent variables are GDP per capita, EPU, RE Consumption (RENE), Financial Development (FD), and Technological Innovation (TIN). GDP^2 is included in the model to test whether the EKC hypothesis is valid. The next section explain the methodology, which we provided in Fig. 4.

Methodology

Cross-section dependency test and unit root test

Cross-sectional dependence must be assessed when panel data are utilized to analyze the presence of a unit root. First generation unit root tests can be applied if the panel data set rejects the existence of cross-section dependence. However, utilizing 2nd generation unit root tests can help us produce more reliable, effective, and potent estimates if there is cross-sectional dependence in the panel data.

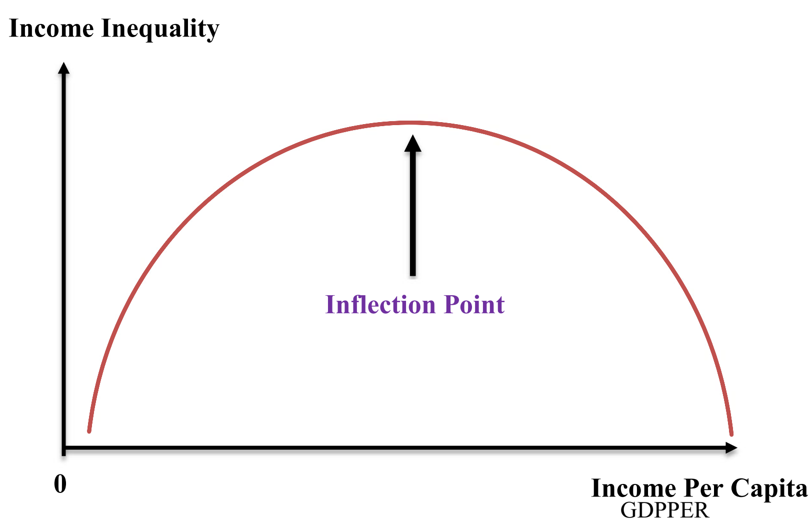


Fig. 2 Traditional Kuznets Curve

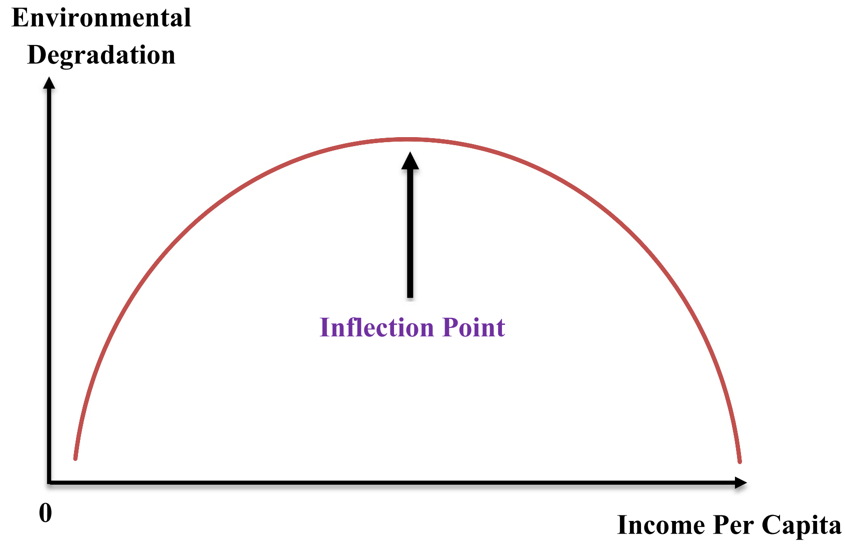


Fig. 3 Environmental Kuznets Curve

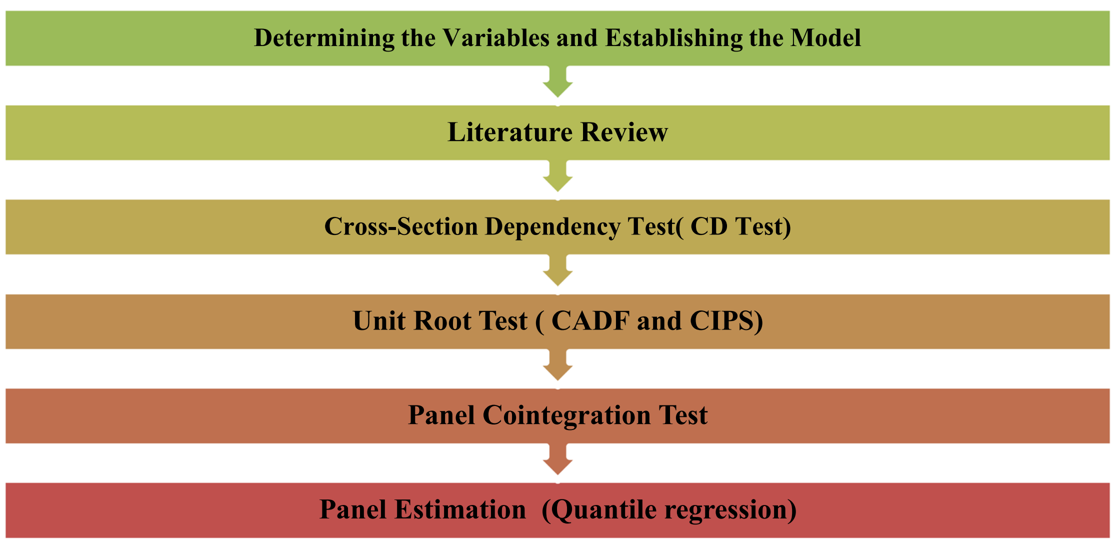


Fig. 4 Flow Chart of the Methods and Methodology of the Study

Cross-sectional dependence can be demonstrated using a variety of tests in the literature. For instance, the CD test created by Pesaran (2004) gives reliable results in panel data where the time dimension is larger than the unit size or the time dimension is smaller than the unit size. Due to this, the cross-sectional dependence of the study's data was examined using Pesaran's (2004) CD test.

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)} \sum_{i=1}^{N-1} \cdot \sum_{J=\dot{I}+1}^{N} \mathrm{ij}^2} - 1 \quad (4)$$

One of the most important issues to be considered to reach the right result while performing econometric analysis is that the series are stationary. Since panel data models also include a time dimension, stationarity analysis should be done first. To determine if the series are stationary or not, certain tests must be performed. The unit root test, which checks for the existence of a unit root in the data, is one method for figuring out whether a time series is stationary. Since the work by Levin, Lin (1992, 1993), and Quah (1994), the unit root panel has also taken an important place in the empirical analysis of data. Thus, the Peseran (2007) CIPS method and the Peseran (2003) CADF test were applied in this study's context.

Panel cointegration test

In Pedroni cointegration analysis, there are seven cointegration statistics. Three of these statistics are between the groups (between dimensions), while the remaining four are within the group (within dimensions) (Asteriou and Hall, 2007). Non-parametric tests make up the first three statistics of in-group statistics. A variance ratio-type statistic is used in the first test. Both the second and third are comparable to the Phillips Peron (PP) (rho) and PP (t) statistics, respectively. The Augmented Dickey-Fuller (ADF) (t) statistic is a parametric statistic that makes up the fourth statistic. Cointegration tests are based on the group mean technique in statistics between groups. The first test in the group is comparable to PP (rho) statistics, while the other two tests are comparable to PP (t) and ADF (t) data (Pedroni 2004). Panel cointegration tests from Kao (1999) and Johansen Fisher (1999) were utilized to assess the dependability of Pedroni's (2004) tests.

Panel estimation techniques

The quantile regression analysis approach created by Koenker and Bassett (1978) is more flexible than the EKC method and was developed based on median regression to overcome the difficulty that arises when the dependent variable is asymmetrically distributed. Binder and Coad (2011) stated that the panel quantile method gives more reliable results because it ignores the mean effects of other coefficient estimation methods. The quantile analysis provides a great advantage over classical regression methods as it can perform regression conditional quantitative estimation and predict the behavior of each particular point in the conditional distribution (Alharthi et al. 2021). In essence, the quantile regression approach allows the distribution of the effect of a change in the independent variable on the dependent variable to be interpreted in different slices. The quantile regression model is a layout model, and the simple location model is as in Eqs. 4 and 5;

$$Y_i = X_i\beta\tau + \varepsilon_i^{\tau} \tag{5}$$

$$Q\tau\left(y_i X_i\right) = X_i^{\tau}\beta_{\tau} \tag{6}$$

Here, $\beta\tau$; the τ'th quantile represents the anticipated coefficient for the regression [$0<\tau<1$], and ε_i^{τ} represents the error term.

$$Y_{i,t} = a_i + \beta_{\tau,1}X1_{i,t} + \beta_{\tau,2}X2_{i,t} \ldots\ldots\ldots. + \beta_{\tau,m}Xm_{i,t} + \varepsilon_{i,\tau} \tag{7}$$

where, i shows the unit (country, business) and t represents time.

Results and discussions

Statistical information about the variables included in the research is given in Table 3. Table 4 demonstrates that technological innovation (TIN), with an average of 9.574, is the variable with the highest average, and the variable with the lowest average is EPU with an average of -1.542. Economic growth (GDP) is shown to have the highest standard deviation with a value of 2.254, and the variable with the lowest is financial development (FD) with 0.556. Among other variables, the average change in economic growth (GDP) is 7.548, the average change in environmental degradation (DGI) is 0.161, the average change in RE consumption is 3.269, and the average change in financial development (FD) is 3.859.

Skewness, Kurtosis, and Jargua-Bera analyses are used to test whether the series has a normal distribution. When the values of Skewness and Kurtosis fall within the range of -1.5 and + 1.5, the series is described as having a regular distribution (Tabachnick and Fidell 2013). The coefficient values of all the variables fall within the range of -1.5 and + 1.5, as mentioned in the literature, and when the Skewness test results are analyzed, it can be argued that all the variables exhibit a normal distribution because their coefficient values fall within this range. When the Kurtosis values are examined, it can be said that the series shows

Table 4 Summary statistics

	DGI	GDP	EPU	RENE	FD	TIN
Mean	0.161	7.548	-1.542	3.269	3.859	9.574
Median	0.002	8.889	-1.505	3.497	3.784	8.933
Maximum	2.507	9.629	0.599	3.984	4.958	14.24
Minimum	-4.135	3.063	-3.579	2.280	3.044	6.729
Std. Dev	1.566	2.254	0.796	0.592	0.556	1.743
Skewness	-0.302	-1.085	-0.040	-0.387	0.531	1.161
Kurtosis	2.582	2.594	2.793	1.487	2.100	3.769
Jarque–Bera	2.615	23.59	0.236	13.95	9.373	28.92
Probability	0.270	0.000	0.888	0.000	0.009	0.000
Observations	120	120	120	120	120	120

a normal distribution since the Kurtosis value of all the variables except the RENE variable is greater than the values of -1.5 and + 1.5 expressed in the literature. The Jarque–Bera test, which displays the statistical outcomes of the error terms, was once again used to determine whether the series demonstrated a normal distribution. The H0 hypothesis, which claims that the error terms are regularly distributed, was not disproved by the test because all of the variables' Chi(2) values were greater than 0.05, which implied that the series had a normal distribution. When the series is normally distributed, traditional regression methods can be used, as well as the quantile regression method.

When Table 5 is examined, Pesaran's (2004) CD test statistic values are seen for the inter-unit correlation of the data. In light of the test results, it was determined that there was a correlation between units for all variables except the EPU variable, and thus the H0 hypothesis that "there is no inter-unit correlation" was invalid.

Table 6 displays the variables' stationarity at the I[0] and I[1] levels based on the outcomes of the CIPS and CADF unit root tests. Upon looking at Table 3, it is clear that the GDP and RENE data are not stationary at the I[0] level. Yet, when calculating their first-order differences, the CIPS unit root test result demonstrates that they are stationary at the I[1] level. Other variables can be demonstrated to be stationary at the I[0] level. Similarly, the findings of the CADF unit root test indicate that the GDP, RENE, and FD variables are not stationary at the I[0] level but become stationary at the I[1] level when their first-order differences are taken into account. At the I[0] level, several variables can be seen to be stationary.

Table 7 shows the panel and group statistics and probability values of the Pedroni (2004) panel cointegration test. The panel v and panel rho statistics are not significant; however, the panel PP and panel ADF are statistically significant at the 1% level when the table is examined. The group statistics show that, with the exception of group ADF, all data are statistically significant at the 1% level. When the results of the Pedroni cointegration test are taken as a whole, four of the seven tests that make up the panel and group statistics show significant cointegration between the series. The Pedroni cointegration test rejected the H0 claim that "there is no cointegration between the series".

Table 8 provides the outcomes of Johansen Fisher and Kao cointegration test. The null hypothesis "there is no cointegration between the series" was rejected at a statistical significance level of 1% when the results of the Johansen-Fisher panel cointegration test were assessed according to the probability values of trace and max-eigen statistics. As a result, it was discovered that the variables have a long-term link and that the alternative theory, "there is cointegration between the series," is true.

Table 5 Results of the cross-sectional dependency test

Indicator	CD test
EDI	(11.139)***
GDP	(13.138)***
EPU	(0.526)
RENE	(6.112)***
FD	(11.209)***
TIN	(8.947)***

Table 6 Unit root test

Indicator	CIPS test		CADF test	
	I[0]	I[1]	I[0]	I[1]
EDI	-2.750***	-	-3.090***	-
GDP	-1.399	-3.500***	-1.423	3.359***
EPU	-3.673***	-	-2.877***	-
RENE	-1.074	-3.343***	-1.385	-3.343***
FD	-2.356**	-	-2.356*	-3.457***
TIN	-3.030***	-	-3.030***	-

Table 7 Panel Cointegration (Pedroni 2004)

Estimates	Stats	Prob
Panel v Statistics	-2.395	0.991
Panel rho Statistics	1.886	0.970
Panel PP Statistics	-3.552	0.000
Panel ADF Statistics	-2.854	0.002
Alternative hypothesis: individual AR coefficient		
Group rho Statistic	2.617	0.995
Group PP Statistic	-4.496	0.000
Group ADF Statistic	-3.916	0.000

Table 8 Cointegration test by Johansen fisher panel

Hypothesized No of CE(s)	Fisher Stat.*			
	From trace test	*p*-value	From max-eigen test	*p*-value
None	450.3	0.0000	577.3	0.0000
At most 1	166.9	0.0000	106.7	0.0000
At most 2	79.38	0.0000	44.01	0.0035
At most 3	46.66	0.0016	32.06	0.0764
At most 4	29.00	0.1448	21.91	0.4654
At most 5	22.31	0.4415	22.31	0.4415
Kao-cointegration Test				
ADF			t-statistics	*p*-value
			-1.860	0.031

The H_0 hypothesis, which states " Between the series, there is no cointegration," was rejected at the 5% level of significance when the Kao cointegration test results were analyzed since the probability value was less than 0.05. (0.031). In light of this, it was decided to accept the alternative hypothesis that "there is cointegration between the series".

Figure 5 shows the frequency distribution of the data, which confirms the data's non-normality, so we apply panel quantile regression. In Table 9, the low (25%), medium (50%), and high (75%) panel quantile regression coefficients, standard error, and probability values of the variables included in the research are given. When the table is examined, it can be observed that all other variables are statistically significant at a 1% level of significance at all quantile levels, despite the fact that the influence of technological innovation (TIN) on environmental degradation is not significant at a high (75%) quantile level.

Examining how economic expansion affects environmental deterioration, low (25%), medium (50%), and high (75%) quantiles are positive and statistically significant at a 1% level of significance. As a result of this finding, a 1% rise in economic growth at a low (25%) quantile level causes a growth of 0.194% in environmental degradation. Likewise, a 1% rise in economic growth at the medium (50%) quantile level causes a rise of 0.447 units in environmental degradation and an increase of 0.250 units at the high (75%) quantile level. Additionally, this outcome shows that the EKC is valid. So, until economic growth hits a "turning point," environmental degradation will continue to rise along with economic development in the early phases of economic development. Because in this process, new technologies will be used in production, new supply chain methods and distribution channels will be used, and nature will be abused at an undesirable level, which will positively affect economic growth and negatively affect environmental quality. However,

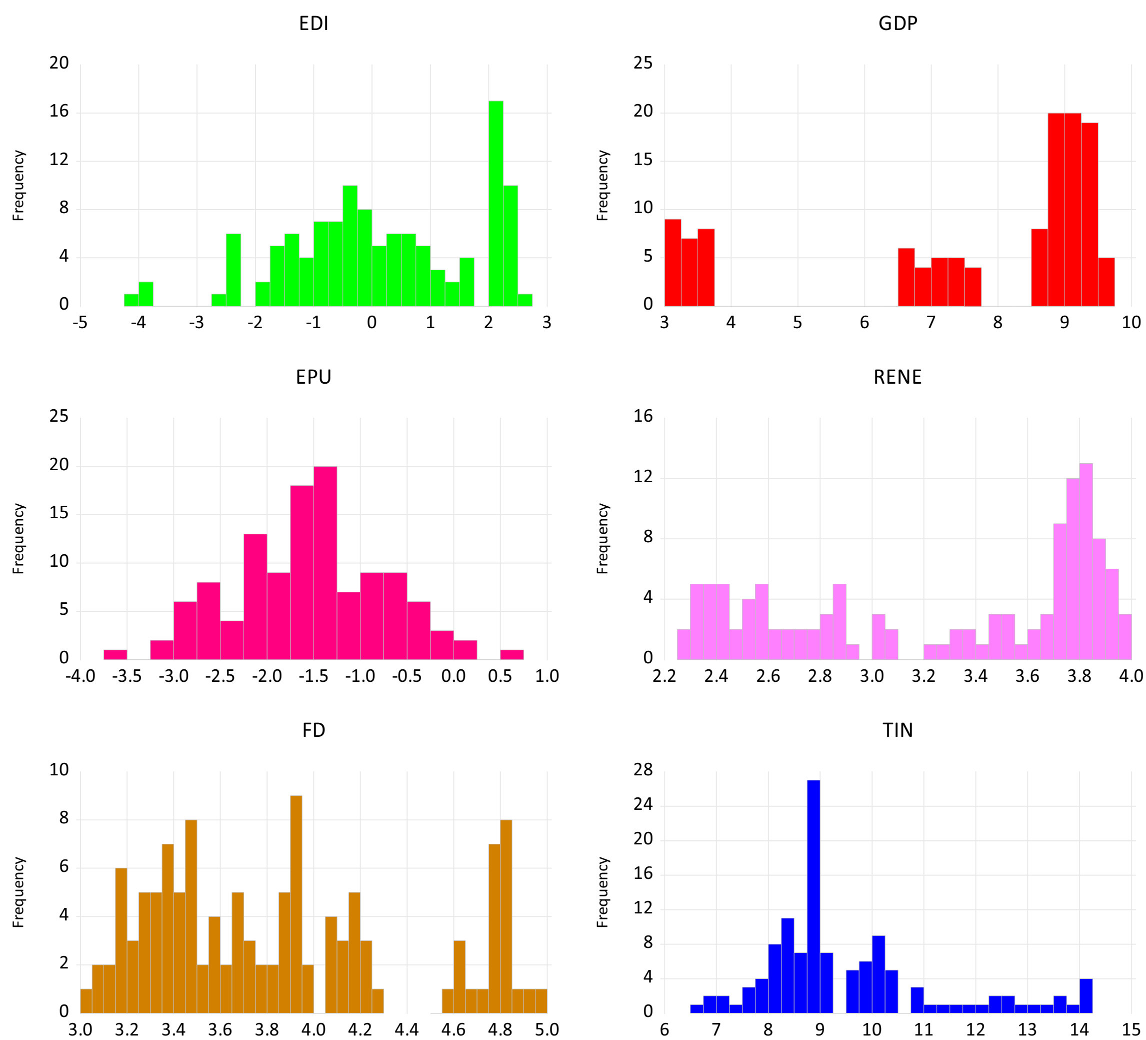


Fig. 5 Frequency distribution of the data

Table 9 The findings of panel quantile regression

Indicators	Outcome of Quantile		
	25th	50th	75th
Coefficients of GDP	**0.194*****	**0.447*****	**0.250*****
St. Error	0.056	0.066	0.060
P-value	0.000	0.000	0.000
Coefficients of GDP^2	**-0.626*****	**-0.731*****	**-0.448*****
St. Error	0.219	0.237	0.200
P-value	0.005	0.002	0.000
Coefficients of EPU	**0.904*****	**0.535*****	**0.429*****
St. Error	0.160	0.164	0.150
P-value	0.000	0.001	0.005
Coefficients of RENE	**-0.604*****	**-0.502*****	**-0.557*****
St. Error	0.170	0.183	0.174
P-value	0.000	0.000	0.001
Coefficients of FD	**-0.446*****	**-0.946*****	**-0.570*****
St. Error	0.151	0.189	0.183
P-values	0.004	0.000	0.002
Coefficients of TIN	**0.315*****	**0.215*****	**0.039**
St. Error	0.074	0.078	0.069
P-values	0.000	0.007	0.5731

"***" shows to 1 percent and "**" shows to 5 percent level of significance

as a result of the developments in the economy, environmental pollution and/or environmental degradation will tend to decrease, and environmental quality will improve by using environmentally friendly new technologies, supply chain methods, distribution channels, and configurations. In other words, economic development and environmental quality will start to resemble an inverted U. These findings concur with findings from previous research published in the literature (Yan et al. 2022; Martins et al. 2021; Ahmad et al. 2021a, b; Salari et al. 2021; Khan et al. 2020a, b; Dong et al. 2018).

When the effect of economic expansion squared on environmental degradation is considered, the low (25%), medium (50%), and high (75%) quantiles are negative and statistically significant at a 1% level. As a result of this finding, a 1% increase in the square of economic growth at a low (25%) quantile level causes a 0.626% decrease in environmental degradation. Likewise, a 1% increase in the square of economic growth at the medium (50%) quantile level causes a 0.731 unit decrease in environmental degradation and a 0.448 unit decrease at the high (75%) quantile level. Examining the research's findings reveals that the EKC is valid because of both the positive impact of economic growth on environmental deterioration and the detrimental effect of its square. These findings concur with those of research that has been published in the literature (Sultana et al. 2022; Yeter et al. 2021; Sarac and Yaglikara, 2017; Gunduz 2014).

Examining how RE affects environmental deterioration, low (25%), medium (50%), and high (75%) quantiles are all statistically significant and negative at a 1% significance level. According to this finding, environmental deterioration is reduced by 0.604% for every 1% increase in RE at a low (25%) quantile level. Similarly, at the medium (50%) quantile level, a 1% increase in RE results in a 0.502% drop in environmental deterioration and a 0.557% decrease at the high (75%) quantile level. Energy from renewable sources can help enhance environmental quality, whereas non-RE sources are widely acknowledged to be the primary cause of environmental degradation (Majeed and Lui, 2019). Since RE will not release polluting gases into the environment, it may increase environmental quality. Likewise, RE can reduce environmental degradation when used as a substitute for fossil fuels. RE also has a positive impact on environmental quality since it conserves resources from mining and resource extraction because it is non-depletable, unlike fossil fuels. Furthermore, by creating dynamic effects through economies of scale and spillover effects, RE enhances environmental quality. Using RE sources to generate electricity allows for the avoidance of thermal pollution brought on by conventional power sources, which is another way that RE improves environmental quality (Majeed and Lui, 2019). The theoretical literature largely indicates that RE has a positive impact on improving environmental quality. The result of the study also supports this theoretical literature. These findings concur with findings from previous research in the literature (Namahoro et al. 2021; Majeed and Lui, 2019; Charfeddine and Kahia 2019; Adams and Nsiah 2019; Sharif et al. 2019; Haseeb et al. 2018).

When the link between financial development and environmental deterioration is examined, the low (25%), medium (50%), and high (75%) quantiles are all statistically significant at a 1% level of significance for being negative. The present study indicates that a 1% rise in financial development at a low (25%) quantile level results in a 0.446 unit reduction in environmental deterioration. Likewise, a 1% increase in financial development at the medium (50%) quantile level causes a 0.946 unit reduction in environmental degradation and a 0.570% unit decrease at the high (75%) quantile level. Financial development can support firms in expanding their economies of scale, enhancing new manufacturing methods or innovations, encouraging investment in environmental projects, and promoting environmentally responsible conduct. The introduction of more ecologically friendly technologies in place of polluting ones can be accelerated by financial development to reduce environmental damage (Liu et al. 2022). The study's findings also imply that, for the reasons given below, there is a bad link between financial development and environmental deprivation. The results of the analysis are in line with several studies in the literature (Amin et al. 2022; Vo et al. 2021; Koçak, 2017; Al-mulali et al. 2015; Shahbaz et al. 2013; Tamazian & Rao 2010).

Assessing how technological innovation affects environmental deterioration, low (25%) and medium (50%) quantiles are positive and statistically significant at a 1% level. This finding shows that a 1% rise in technological innovation generates an increase in environmental degradation of 0.315% at the low (25%) quantile level and 0.215% at the medium (50%) quantile level. No significant effect was discovered at a high (75%) quantile level. A body of research has shown that there is a positive and negative link between technological innovation and environmental deterioration (Adebayo et al. 2022). Environmental deterioration is reduced if technological innovations are made toward ecologically friendly technologies. Environmental deterioration will result, however, if technical progress is not achieved in fields that are environmentally beneficial. The results obtained are consistent with previous research (Kirikkaleli et al. 2022; Liv et al. 2022; Dauda et al. 2021; Ganda 2019; Bekhet & Othman 2017; Costantini et al. 2017). Essentially, the use of RE resources benefits from high-volume technological innovation, but it is obvious that many of the minerals used in cutting-edge technology have a negative impact on the environment (Kilinc-Ata et al. 2023). Because of this, technological innovation is insignificant in the next quantile, even though it causes environmental harm in the first quantile. According to several recent studies by Murgua & Bastida (2023), Eraky et al. (2022), and Omotehinse & Ako (2019), the usage of mineral resources in RE infrastructure has serious negative consequences for the environment.

Conclusion and policy implications

In the twenty-first century, how to prevent environmental damage and establish a sustainable economic framework is one of the most frequently asked questions. Many theoretical and empirical studies have been done on this topic. The aim of the current paper is to add to the body of literature on the so-called "fragile five" nations. To achieve this aim, panel Cointegration and Quantile Regression Model were used to examine the impact of production volume (GDP), EPU, technological innovation (TIN), RE consumption (RENE), and financial development (FD) on environmental degradation (EDI).

The current paper demonstrated that the parameters had long-term relationships. The quantile regression findings demonstrate that GDP increases the EDI, but the rate of increase decreases as the quantile level increases. In contrast, GDP^2 was found to increase EDI. This bidirectional movement of GDP with EDI confirms the relationship assumed by the EKC with an inverted "U" shape between the two variables. Another result, which means that it increases EDI and worsens the environment, belongs to EPU. While EPU affects EDI at low quantile levels, this effect appears to decrease at high quantile levels. This result may be due to the postponement of investments in environmentally friendly production technologies due to uncertainties in economic policy, the more widespread use of old and environmentally polluting production techniques, and the lack of use of RE systems that require long-term investments. The results show that this hypothesis is further supported by the inverse link between RE use and EDI. Although the effect of RENE on EDI decreased as the quantile level increased, significant results were obtained at all quantile levels. It is not surprising that the increased usage of RE is reducing environmental degradation. This result supports the findings of Sarkodie & Adams (2018), Zhang & Liu (2019), Anwar et al. (2021), Mehmood (2021), and Kartal (2022) studies in the literature. One of the most important obstacles to taking environmental protective measures and developing technologies that protect the environment is financial constraint. Findings reveal that FD reduces EDI. It was also revealed that FD reduces EDI more stably at moderate and high levels of environmental degradation. This result supports the findings of Shahbaz et al. (2016), Acheampong (2019), Ibrahiem (2020), Ahmad et al. (2022), and Kilinc-Ata & Alshami (2023). It was concluded that TIN increased EDI at low quantile levels. Although Popp et al. (2010), Stamford & Azapagic (2018), and Yang et al. (2021) have revealed that technological innovations have a positive effect on environmental protection, the findings obtained in this study are also very important. Because TIN's fueling of environmental degradation shows that technological developments are not focused on environmental protection within the framework of the country group examined.

Given these findings, we made a few policy recommendations. Firstly, the policymakers of the countries need to design growth-oriented policies and strategies to control environmental degradation in these countries. Monetary and fiscal policies should be reconstructed, taking into account the environmental effects of growth. Since it is known that the increase in production and income will bring about a structural transformation in the economy, this transformation should be supported by environmentally friendly green production technologies and RE adaptation. And legal regulations, incentives, joint ventures, some tax exemptions, and subsidies should be provided for this transformation. It is crucial to provide companies and individuals who invest in goods or services connected to RE with tax exemptions, reductions, or incentives. In other words, governments/policymakers should support both market pull policies as well as technology push policies.

A number of market pull and technological push policies were evaluated as being extremely effective overall, showing that effective policy did actually spur private equity fund managers to participate in emerging RE technologies. The best technology push policies were recognized as government subsidies, tax exemptions, joint ventures, and incentives. Considering that the most important pollutants are fossil fuels, energy policy will have a substantial impact on environmental deterioration and the structural development of the economy.

Policymakers should keep in mind the importance of the EPU and the environmental impact of increases in the EPU. Two different policies can be developed to adress the link between EPU and environmental degradation. The first of these are policies aimed directly at reducing the EPU. Increasing economic predictability, the functioning of the economy according to the rules, spreading transparency to economic decisions, strong financial institutions, etc. are a few examples of ways to reduce the EPU. The other option is to weaken the links between the EPU and environmental degradation. Thus, the increase in EPU will not contribute to environmental degradation, or this contribution would be limited. High EPU causes production by traditional methods, the uncontrolled use of natural resources, and the withdrawal of investments from environmentally friendly technology areas and RE sources. Incentives and tax cuts to be given to these areas will weaken the inverse link between EPU and EDI.

It is necessary to create policies that promote the generation and use of RE. The return on investment required for RE production may take years. This situation is a deterrent for investors to produce RE. For this reason, the governments of the countries examined in the study are subject to supportive positions such as tax exemptions, subsidies, land allocation, tax refunds, joint ventures, low-interest fund allocation, etc. International conferences and pieces of training can be organized to increase social consciousness about RE production and consumption. There are several unfavorable effects of the policy suggestions to use RE resources more frequently. For instance, encouraging the development of RE will lead to higher demand for specific mineral resources. For instance, several critical minerals utilized in the construction of RE infrastructure have a severe impact on the environment and may have supply issues in the future.

The findings of this study show that technological innovations are a variable that causes environmental degradation. Efforts to improve technology need to be directed towards the development of environmentally friendly technologies. Rewarding efforts focused on the development of labor-saving or capital-saving technologies, as well as the development of technologies that save natural resources, consume less energy, and generate less waste, maybe the right strategy.

Financial development is located at the intersection of the production of RE and technological innovations. Ensuring financial development can act as a catalyst by creating momentum for both variables. Developing financial opportunities, deepening financial markets, increasing the number of ATMs/banks per capita, and spreading financial literacy in society constitute the parameters of financial development. As can be understood, these parameters have educational, technical, and financial aspects. In addition, environmental participants should not be forgotten. Therefore, policies to be developed and implemented for financial development can be realized with the participation of different components of society. Bringing these components together and giving them the necessary incentives can combine financial development with environmental concerns.

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References

Abbasi KR, Adedoyin FF (2021) Does energy use and economic policy uncertainty affects CO_2 emissions in China? Empirical evidence from the dynamic ARDL simulation approach. Environ Sci Pollut Res 28:23323–23335

Abulfotuh F (2007) Energy efficiency and renewable technologies: the way to sustainable energy future. Desalination 209(1):275–282. https://doi.org/10.1016/j.desal.2007.04.040

Acaravci A, Oztürk I (2010) On the relationship between energy consumption CO_2 emissions and economic growth in Europe. Energy 35:5412–5420

Acheampong A (2019) Modeling for insight: Does financial development improve environmental quality? Energy Economics 83:156–179. https://doi.org/10.1016/j.eneco.2019.06.025

Adams S, Nsiah C (2019) Reducing Carbon Dioxide Emissions; Does Renewable Energy Matter? Sci Total Environ 693:133288. https://doi.org/10.1016/j.scitotenv.2019.07.094

Adebanjo SA, Shakiru TH (2022) The dynamic relationship between air pollution and economic growth in Jordan: an empirical analysis. Environ Sci Econ 1(2):30–43

Adebayo TS, Kirikkaleli D (2021) Impact of renewable energy consumption, globalization, and technological innovation on environmental degradation in Japan: application of wavelet tools. Environ Dev Sustain 23(11):16057–16082

Adebayo TS, Akadiri SS, Akanni EO, Sadiq & Bamgbopa, Y. (2022a) Impact of renewable energy consumption, globalization, and technological innovation on environmental degradation in Japan: application of wavelet tools. Environ Sci Pollut Res 2022(29):32287–32297. https://doi.org/10.1007/s11356-022-20002-w

Adebayo TS, Rjoub H, Akinsola GD, Oladipupo SD (2022b) The asymmetric effects of renewable energy consumption and trade openness on carbon emissions in Sweden: new evidence from quantile-on-quantile regression approach. Environ Sci Pollut Res 29(2):1875–1886

Adebayo TS, Oladipup SD, Kirikkaleli D, Adeshola I (2022c) Asymmetric nexus between technological innovation and environmental degradation in Sweden: an aggregated and disaggregated analysis. Environ Sci Pollut Res 29:36547–36564. https://doi.org/10.1007/s11356-021-17982-6

Adedoyin FF, Zakari A (2020) Energy consumption, economic expansion, and CO_2 emission in the UK: the role of economic policy uncertainty. Sci Total Environ 738:140014

Ahmad M, Jabeen G, Wu Y (2021a) Heterogeneity of pollution haven/halo hypothesis and environmental Kuznets curve hypothesis across development levels of Chinese provinces. J Clean Prod 285:124898

Ahmad M, Muslija A, Satrovic E (2021b) Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. Environ Sci Pollut Res 28(18):22588–22601

Ahmad M, Ahmed Z, Yang X, Hussain N, Sinha A (2022) 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 N, Youjin L, Zikovi S, Belyaeva Z (2023) The effects of technological innovation on sustainable development and environmental degradation: Evidence from China. Technol Soc 72(2023):102184

Al-mulali U, Lee JYM, Mohammed AH, Sheau-Thing L (2013) Examining the link between energy consumption, carbon dioxide emission and economic growth in Latin America and the Caribbean. Renew Sust Energ Rev 26:42–48

Al-Mulali U, Tang CF, Ozturk I (2015) Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. Environ Sci Pollut Res 22(19):1–10. https://doi.org/10.1007/s11356-015-4726-x

Alvarado R, Toledo E (2017) Environmental degradation and economic growth: evidence for a developing country. Environ Dev Sustain 2017(19):1205–1218. https://doi.org/10.1007/s10668-016-9790-y

Amin A, Ameer W, Yousaf H, Akbar M (2022) Financial development, institutional quality, and the influence of various environmental factors on carbon dioxide emissions: exploring the Nexus in China. Front Environ Sci 9:838714. https://doi.org/10.3389/fenvs.2021.838714

Ansari MA (2022) Re-visiting the Environmental Kuznets curve for ASEAN: a comparison between ecological footprint and carbon dioxide emissions. Renew Sustain Energy Rev 168:112867

Anser MK, Apergis N, Syed KR (2021) Impact of economic policy uncertainty on CO_2 emissions: Evidence from top ten carbon emitter countries. Environ Sci Pollut Res 2021(28):29369–29378. https://doi.org/10.1007/s11356-021-12782-4

Anwar A, Malik S (2021) Cogitating the role of technological innovation and institutional quality on environmental degradation in G-7 countries. Int J Green Econ 15(3):213–232

Anwar A, Sharif A, Fatima S, Ahmad P, Sinha A, Khan SAR, Jermsittiparsert K (2021b) The asymmetric effect of public private partnership investment on transport CO2 emission in China: Evidence from quantile ARDL approach. J Clean Prod 288:125282

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

Anwar A, Chaudhary AR, Malik S (2023) Modeling the macroeconomic determinants of environmental degradation in E-7 countries: the role of technological innovation and institutional quality. J Public Aff 23(1):e2834

Anwar, A., Chaudhary, A. R., Malik, S., & Bassim, M. (2021a). 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, 09721509211039392.

Anwar, A., Sinha, A., Sharif, A., Siddique, M., Irshad, S., Anwar, W., & Malik, S. (2021d). The nexus between urbanization, renewable energy consumption, financial development, and CO 2 emissions: Evidence from selected Asian countries. Environ Dev Sustain, 1–21

Anwar, A., Malik, S., & Ahmad, P. (2022). Cogitating the role of technological innovation and institutional quality in formulating the sustainable development goal policies for E7 countries: evidence from quantile regression. Glob Bus Rev, 09721509211072657

Arouri MEH, Youssef AB, M'henni, H., Rault, C., (2012) Energy consumption, economic growth and CO_2 emissions in Middle East and North African countries. Energy Policy 45:342–349

Asongu SA, Le Roux S, Biekpe N (2018) Enhancing ICT for environmental sustainability in sub-Saharan Africa. Technological Forecasting and Social Change 127:209–216

Bai Y, Deng X, Gibson J, Zhao Z, Xu H (2019) How does urbanization affect residential CO2 emissions? An analysis on urban agglomerations of China. J Clean Prod 209:876–885. https://doi.org/10.1016/j.jclepro.2018.10.248

Barut A, Kaya E, Bekun FV, Cengiz S (2023) Environmental sustainability amidst financial inclusion in five fragile economies: Evidence from lens of environmental Kuznets curve. Energy 269(2023):12680. https://doi.org/10.1016/j.energy.2023.126802

Bekhet HA, Othman NS (2017) Impact of urbanization growth on Malaysia CO_2 emissions: evidence from the dynamic relationship. J Clean Prod 154:374–388. https://doi.org/10.1016/j.jclepro.2017.03.174

Biswas AK, Farzanegan MR, Thum M (2012) Pollution, shadow economy and corruption: theory and evidence. Ecol Econ 75(C):114–125. https://doi.org/10.1016/j.ecolecon.2012.01.007

Boukhelkhal A (2022) Energy use, economic growth and CO_2 emissions in Africa: does the environmental Kuznets curve hypothesis exist? New evidence from heterogeneous panel under cross-sectional dependence. Environ Dev Sustain 24(11):13083–13110

BP Energy Outlook. 2022. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2022.pdf

Cai Y, Xu J, Ahmad P, Anwar A (2022) What drives carbon emissions in the long-run? The role of renewable energy and agriculture in achieving the sustainable development goals. Econ Res-Ekonomska Istraživanja 35(1):4603–4624

Canaj K, Mehmeti A, Morrone D, Toma P, Todorovi´c, M., (2021) Life cycle-based evaluation of environmental impacts and external costs of treated wastewater reuse for irrigation: a case study in southern Italy. J. Cleaner Prod 293:126142. https://doi.org/10.1016/j.jclepro.2021.126142

Candau F, Dienesch E (2017) Pollution haven and corruption paradise. J Environ Econ Manag 85(C):171–192. https://doi.org/10.1016/j.jeem.2017.05.005

Charfeddine L, Kahia M (2019) Impact of Renewable Energy Consumption and Financial Development on CO_2 Emissions and Economic Growth in the MENA Region: A Panel Vector Autoregressive (PVAR) Analysis. Renew Energ 139:198–213. https://doi.org/10.1016/j.renene.2019.01.010

Charfeddine L, Mrabet Z (2017) The impact of economic development and socialpolitical factors on ecological footprint: a panel data analysis for 15 MENA countries. Renew Sustain Energy Rev 76:138–154. https://doi.org/10.1016/j.rser.2017.03.031

Chen Q, Taylor D (2020) Economic development and pollution emissions in Singapore: Evidence in support of the Environmental Kuznets Curve hypothesis and its implications for regional sustainability. J Clean Prod 243:118637

Cheng C, Ren X, Dong K, Dong X, Wang Z (2021) How does technological innovation mitigate CO_2 emissions in OECD countries? Heterogeneous analysis using panel quantile regression. J Environ Manage 280:111818

Chien T, Hu JL (2008) Renewable energy: an efficient mechanism to improve GDP. Energy Policy 36(8):3045–3052. https://doi.org/10.1016/j.enpol.2008.04.012

Chien F, Anwar A, Hsu CC, Sharif A, Razzaq A, Sinha A (2021) The role of information and communication technology in encountering environmental degradation: proposing an SDG framework for the BRICS countries. Technol Soc 65:101587

Çitil, M., İlbasmış, M., Olanrewaju, V. O., Barut, A., Karaoğlan, S., & Ali, M. (2023). Does green finance and institutional quality play an important role in air quality. Environ Sci Pollut Res, 1–15.

Costantini V, Crespi F, Marin G, Paglialunga E (2017) Eco-innovation, Sustainable Supply Chains and Environmental Performance in European Industries. J Clean Prod 155:141–154. https://doi.org/10.1016/j.jclepro.2016.09.038

Cronin RP, Pandya A (2009) Exploiting natural resources: Growth, instability, and conflict in the Middle East and Asia. Henry L. Stimson Center, Washington

Dai H, Xie X, Xie Y, Liu J, Masui T (2016) Green growth: the economic impacts of large-scale renewable energy development in China. Appl Energy 162:435–449. https://doi.org/10.1016/j.apenergy.2015.10.049

Dauda L, Long X, Mensah CN, Salman M, Boamah KB, Ampon-Wireko S, Kof Dogbe CS (2021) Innovation, trade openness and CO_2 emissions in selected countries in Africa. J Clean Prod 281:125143. https://doi.org/10.1016/j.jclepro.2020.125143

Depren SK, Kartal MT, Çelikdemir Çoban N, Depren Ö (2022) Energy consumption and environmental degradation nexus: A systematic review and meta-analysis of fossil fuel and renewable energy consumption. Ecological Informatic 70:101747. https://doi.org/10.1016/j.ecoinf.2022.101747-1090

Dogan E, Turkekul B (2016) CO2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. Environ Sci Pollut Res 23:1203–1213. https://doi.org/10.1007/s11356-015-5323-8

Dogan E, Ulucak R, Kocak E, Isik C (2020) The use of ecological footprint in estimating the environmental Kuznets curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. Sci Total Environ 723:138063

Dong K, Hochman G, Zhang Y, Sun R, Lİ H, Liao H (2018) CO_2 Emissions, economic and population growth, and renewable energy: empirical evidence across regions. Energy Economics 75(1):180–192. https://doi.org/10.1016/j.eneco.2018.08.017

Elif A, Gul IT, Serap TA (2011) CO_2 emissions of Turkish manifacturing industry: a decomposition analysis. Appl Energy 88:2273–2278

Eraky M, Elsayed M, Qyyum MA, Ai P, Tawfik A (2022) A new cutting-edge review on the bioremediation of anaerobic digestate for environmental applications and cleaner bioenergy. Environ Res 213:113708

Erdogan S, Okumus I, Guzel AE (2020) Revisiting the Environmental Kuznets Curve hypothesis in OECD countries: the role of renewable, non-renewable energy, and oil prices. Environ Sci Pollut Res 27:23655–23663

Esmaeili P, Lorente DB, Anwar A (2023) Revisiting the environmental Kuznetz curve and pollution haven hypothesis in N-11 economies: Fresh evidence from panel quantile regression. Environ Res 228:115844

Farooq, A., Anwar, A., Ahad, M., Shabbir, G., & Imran, Z. A. (2021). A validity of environmental Kuznets curve under the role of urbanization, financial development index and foreign direct investment in Pakistan. J Econ Admin Sci. Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JEAS-10-2021-0219

Ganda F (2019) The impact of innovation and technology investments on carbon emissions in selected organisation for economic co-operation and development countries. J Clean Prod 217:469–483. https://doi.org/10.1016/j.jclepro.2019.01.235

Gao X, Li X, Chishti MZ, Ullah S, Sohail S (2022) Decomposing the asymmetric efects of terrorism and FDI on carbon emission. Environ Sci Pollut Control Ser 29:41125–39. https://doi.org/10.1007/s11356-021-16955-z

Gioda A (2019) Residential fuelwood consumption in Brazil: environmental and social implications. Biomass Bioenergy 120:367–375. https://doi.org/10.1016/j.biombioe.2018.11.014

Gormus S, Aydin M (2020) Revisiting the environmental Kuznets curve hypothesis using innovation: new evidence from the top 10 innovative economies. Environ Sci Pollut Res 27:27904–27913

Gunduz, H.İ. (2014). Çevre Kirliliği ile Gelir Arasındaki İlişkinin İncelenmesi: Panel Eşbütünleşme Analizi ve Hata Düzeltme Modeli. Marmara Üniversitesi İ.İ.B. Dergisi, XXXVI(I), 409–423. https://doi.org/10.14780/iibdergi.201417554

Guoyan, S., Khaskheli, A., Raza, S. A., & Shah, N. (2022). Analyzing the association between the foreign direct investment and carbon emissions in MENA countries: a pathway to sustainable development. Environ Dev Sustain, 1–18

Gutti B, Aji M, Magaji G (2012) Environmental impact of natural resources exploitation in Nigeria and the way forward. J Appl Technol Environ Sanitation 2(2):95–102

Habiba UMME, Xinbang C, Anwar A (2022) Do green technology innovations, financial development, and renewable energy use help to curb carbon emissions? Renewable Energy 193:1082–1093

Haseeb A, Xia E, Baloch MA, Abbas K (2018) Financial development, globalization, and CO_2 emission in the presence of EKC: evidence from BRICS countries. Environ Sci Pollut Res 25(31):31283–31296. https://doi.org/10.1007/s11356-018-3034-7

Heidari H, Katircioglu ST, Seidpour L (2015) Economic growth, CO_2 emissions and energy consumption in the five ASEAN countries. Int J Electr Power Energy Syst 64:785–791

Helland E, Whitford AB (2003) Pollution incidence and political jurisdiction: evidence from the TRI. J Environ Econ Manag 46(3):403–424. https://doi.org/10.1016/S0095-0696(03)00033-0

Ibrahiem D (2020) Do technological innovations and financial development improve environmental quality in Egypt? Environ Sci Pollut Res 27:10869–10881. https://doi.org/10.1007/s11356-019-07585-7

Intergovernmental Panel on Climate Change (IPCC), 2018. Summary for policymakers. In: Global warming of 1.5◦C. An IPCC special report on the impacts of global warming of 1.5◦C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Islam F, Shahbaz M, Ahmed AU, Alam MM (2013) Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Economic Modelling 30:435–441

Jaunky, V.C., 2010. The CO2 emissions–income nexus: evidence from rich countries., Faculty of Social Studies and Humanities. Department of Economics and Statistics.The University of Mauritius

Jha R, Murthy KV. A critique of the environmental sustainability index. SSRN Electron J 2003:1–28. February

Jolliffe I (2011) Principal Component Analysis. In International Encyclopedia of Statistical Science. Springer, Berlin, Heidelberg, pp 1094–1096

Kao C (1999) Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics 90(1):1–44

Karamizadeh S, Abdullah MS, Manaf MA, Zamani M, Hooman A (2013) An overview of principal component analysis. J Signal Inform Process 4:173–175. https://doi.org/10.4236/jsip.2013.43B031

Kartal M (2022) The role of consumption of energy, fossil sources, nuclear energy, and renewable energy on environmental degradation in top-five carbon producing countries. Renewable Energy 184:871–880. https://doi.org/10.1016/j.renene.2021.12.022

Khan M, Ozturk I (2021) Examining the direct and indirect effects of financial development on CO_2 emissions for 88 developing countries. J Environ Manage 293:112812

Khan A, Chenggang Y, Bano S, Hussain J (2020) The empirical relationship between environmental degradation, economic growth, and social well-being in Belt and Road Initiative countries. Environ Sci Pollut Res 27:30800-30814 (2020). https://doi.org/10.1007/s11356-020-09058-8

Khan SAR, Yu Z, Belhadi A, Mardani A (2020b) Investigating the effects of renewable energy on international trade and environmental quality. J Environ Manage 272:111089

Khan H, Weili L, Khan I (2022) Examining the effect of information and communication technology, innovations, and renewable energy consumption on CO_2 emission: evidence from BRICS countries. Environ Sci Pollut Res 29(31):47696–47712

Kilinc-Ata N and Alshami M (2023) Analysis of how environmental degradation affects clean energy transition: evidence from the UAE. Environ Sci Pollut Res 1–13

Kilinc-Ata N, Alshami M and Munir K (2023) How do strategic mineral resources affect clean energy transition? Cross-sectional autoregressive distributed lag (CS-ARDL) approach. Miner Econ 1–12

Kirikkaleli D, Güngör H, Adebayo TS (2022) Consumption-based carbon emissions, renewable energy consumption, financial development and economic growth in Chile. Bus Strateg Environ 31(3):1123–1137

Kirikkaleli, Abbasi, K. R., Oyebanji, M. O. (2023). The asymmetric and long-run effect of environmental innovation and CO2 intensity of GDP on consumption-based CO2 emissions in Denmark. Environ Sci Pollut Res (2023) 30:50110–50124. https://doi.org/10.1007/s11356-023-25811-1

Kocak E (2017) Finansal Gelişme Çevresel Kaliteyi Etkiler mi? Yükselen Piyasa Ekonomileri için Ampirik Kanıtlar. Uluslararası Yönetim İktisat Ve İşletme Dergisi 13(3):535–552

Koenker R and Bassett Jr G (1978) Regression quantiles. Econometrica 33–50

Krewitt W, Simon S, Graus W, Teske S, Zervos A, Schäfer O (2007) The 2 C scenario—a sustainable world energy perspective. Energy Policy 35(10):4969–4980. https://doi.org/10.1016/j.enpol.2007.04.034

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

Le T-H, Chuc AT, Taghizadeh-Hesary F (2019) Financial inclusion and its impact on financial efficiency and sustainability: empirical evidence from Asia. Borsa Istanbul Rev 19(4):310–322. https://doi.org/10.1016/j.bir.2019.07.002

Liu G, Khan MA, Haider A, Uddin M (2022) Financial development and environmental degradation: promoting low-carbon competitiveness in E7 economies' industries. Int J Environ Res Public Health 19:16336. https://doi.org/10.3390/ijerph192316336

Lv Z, Li S (2021) How financial development affects CO_2 emissions: a spatial econometric analysis. J Environ Manage 277:111397

Majeed, MT., & Luni, T. (2019). Renewable energy, water, and environmental degradation: A global panel data approach. Pak J Commer Soc Sci (PJCSS), 13(3),749–778. http://hdl.handle.net/10419/205276

Martins JM, Adebayo TS, Mata MN, Oladipupo SD, Adeshol İ, Ahmed Z, Correia AB (2021) Modeling the relationship between economic complexity and environmental degradation: evidence from top seven economic complexity countries. Front Environ Sci 9:744781. https://doi.org/10.3389/fenvs.2021.744781

Masron TA, Subramaniam Y (2018) The environmental Kuznets cur5ve in the presence of corruption in developing countries. Environ Sci Pollut Res 25:12491–12506 (**10.1007/**)

Mehmood U (2021) Contribution of renewable energy towards environmental quality: The role of education to achieve sustainable development goals in G11 countries. Renewable Energy 178:600–607. https://doi.org/10.1016/j.renene.2021.06.118

Mehmood U, Tariq S, Haq Z-U, Nawaz H, Ali S, Murshed M, Iqbal M. (2023). Evaluating the role of renewable energy and technology innovations in lowering CO2 emission: a wavelet coherence approach. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-023-25379-w

Mukhtarov S, Aliyev F, Aliyev J, Ajayi R (2023) Renewable energy consumption and carbon emissions: evidence from an oil-rich economy. Sustainability 15(1):134

Mukhtarov, S., 2022. The impact of carbon pricing on international competitiveness in the case of Azerbaijan. Environ Sci Pollut Res. 1–8

Murguía DI, Bastida AE (2023) Critical and energy transition minerals in Argentina: Mineral potential and challenges for strengthening public institutions. Geological Society, London, Special Publications 526(1):SP526-2022

Murshed M, Haseeb M, Alam MS (2022) The environmental Kuznets curve hypothesis for carbon and ecological footprints in South Asia: the role of renewable energy. GeoJournal 87(3):2345–2372

Mutezo G, Mulopo J (2021) A review of Africa's transition from fossil fuels to renewable energy using circular economy principles. Renew Sust Energ Rev 137:110609

Namahoro JP, Wu Q, Xiao H, Zhou N (2021) The impact of renewable energy, economic and population growth on CO_2 emissions in the East African Region: evidence from common correlated effect means group and asymmetric analysis. Energies 14(2):312. https://doi.org/10.3390/en14020312

Narayan S, Doytch N (2017) An investigation of renewable and nonrenewable energy consumption and economic growth nexus using industrial and residential energy consumption. Energy Econ 68:160–176. https://doi.org/10.1016/j.eneco.2017.09.005

Narayan PK, Popp S (2012) The energy consumption-real GDP nexus revisited: empirical evidence from 93 countries. Econ Model 29:303–308

Nejat P, Jomehzadeh F, Taheri MM, Gohari M, Majid MZA (2015) A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). Renew Sust Energ Rev 43:843–862. https://doi.org/10.1016/j.rser.2014.11.066

Nguyen TTH (2021) Measuring financial inclusion: a composite FI index for th developing countries. J Econ Dev 23(1):77–99. https://doi.org/10.1108/JED-03-2020-0027

Ocal O, Aslan A (2013) Renewable energy consumption–economic growth nexus in Turkey. Renew Sust Energ Rev 28:494–499. https://doi.org/10.1016/j.rser.2013.08.036

Olivier JG, Peters JA, Janssens MG (2012) Trends in global CO_2 emissions 2012 report

Omotehinse AO, Ako BD (2019) The environmental implications of the exploration and exploitation of solid minerals in Nigeria with a special focus on Tin in Jos and Coal in Enugu. J Sustain Mining 18(1):18–24

Omri, A. (2020). Technological innovation and sustainable development: does the stage of development matter? Environ Impact Assess Rev. 83 (2020) https://doi.org/10.1016/j.eiar.2020.106398

Pedroni P (2004) Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Economet Theor 20(3):597–625

Popp D, Newell R, Jaffe A (2010) Energy, the environment, and technological change. Handbook Economics Innovation 2:873–937. https://doi.org/10.1016/S0169-7218(10)02005-8

Qayyum M, Ali M, Nizamani MM, Li S, Yu Y, Jahanger A (2021) Nexus between financial development, renewable energy consumption, technological innovations and CO_2 emissions: the case of India. Energies 14(15):4505

Rafique MZ, Li Y, Larik AR, Monaheng MP (2020) The effects of FDI, technological innovation, and financial development on CO 2 emissions: Evidence from the BRICS countries. Environ Sci Pollut Res 27:23899–23913

Ramzan M, Abbasi KR, Salman A, Dagar RA, Kagz M (2023) Towards the dream of go green: An empirical importance of green innovation and financial depth for environmental neutrality in world's top 10 greenest economies. Technological Forecasting & Social Change 189:122370. https://doi.org/10.1016/j.techfore.2023.122370

Raza SA, Shah N (2018) Testing environmental Kuznets curve hypothesis in G7 countries: the role of renewable energy consumption and trade. Environ Sci Pollut Res 2018(25):26965–26977. https://doi.org/10.1007/s11356-018-2673-z

Raza SA, Shahbaz M, Nguyen DK (2015) Energy conservation policies, growth and trade performance: evidence of feedback hypothesis in Pakistan. Energy Policy 80:1–10. https://doi.org/10.1016/j.enpol.2015.01.011

Raza SA, Shah N, Sharif A (2019) Time frequency relationship between energy consumption, economic growth and environmental degradation in the United States: Evidence from transportation sector. Energy 173:706–720. https://doi.org/10.1016/j.energy.2019.01.077

Raza SA, Shah N, Khan KA (2020a) Residential energy environmental Kuznets curve in emerging economies: the role of economic growth, renewable energy consumption, and financial development. Environ Sci Pollut Res 27:5620–5629

Raza RS, Shah N, Khan KA (2020b) Residential energy environmental Kuznets curve in emerging economies: the role of economic growth, renewable energy consumption, and financial development. Environ Sci Pollut Res 2020(27):5620–5629. https://doi.org/10.1007/s11356-019-06356-8

Raza AS, Shah N, Sharif A and Shahbaz M (2022) A revisit of the globalization and carbon dioxide emission nexus: evidence from top globalized economies. In Energy-Growth Nexus in an Era of Globalization. (pp. 383–404). Elsevier

Salari M, Javid RJ, Noghanibehambari H (2021) The Nexus between CO_2 Emissions, Energy Consumption, and Economic Growth in the U.S. Econ Anal Pol 69:182–194. https://doi.org/10.1016/j.eap.2020.12.007

Salazar-Núñez, H. F., Venegas-Martínez, F., & Lozano-Díez, J. A. (2022). Assessing the interdependence among renewable and non-renewable energies, economic growth, and CO_2 emissions in Mexico. Environ Dev Sustain, 1–17

Salem S, Arshed N, Anwar A, Iqbal M, Sattar N (2021) Renewable energy consumption and carbon emissions—testing nonlinearity for highly carbon emitting countries. Sustainability 13(21):11930

Saraç Ş, Yağlıkara A (2017) Environmental Kuznets Curve: The Evidence from BSEC Countries. Ege Akademik Bakış/ Ege Academic Review 17(2):255–264. https://doi.org/10.21121/eab.2017225203

Sarkodie S, Adams S (2018) Renewable energy, nuclear energy, and environmental pollution: Accounting for political institutional quality in South Africa. Sci Total Environ 643:1590–1601. https://doi.org/10.1016/j.scitotenv.2018.06.320

Sekraf H, Sghaier A (2018) Examining the relationship between corruption, economic growth, environmental degradation, and energy consumption: a panel analysis in MENA region. J Knowl Econ 9(3):963–979. https://doi.org/10.1007/s13132-016-0384-6

Shahbaz M, Solarin SA, Mahmood H, Arouri M (2013) Does financial development reduce CO_2 emissions in Malaysian economy? A time series analysis. Econ Model 35:145–152. https://doi.org/10.1016/j.econmod.2013.06.037

Shahbaz M, Shahzad S, Ahmad N, Alam S (2016) Financial development and environmental quality: The way forward. Energy Policy 98:353–364. https://doi.org/10.1016/j.enpol.2016.09.002

Shahbaz M, Raghutla C, Song M, Zameer H, Jiao Z (2020) Public-private partnerships investment in energy as new determinant of CO_2 emissions: the role of technological innovations in China. Energy Economics 86:104664

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

Sharif A, Mishra S, Sinha A, Jiao Z, Shahbaz M, Afshan S (2020) The renewable energy consumption-environmental degradation nexus in Top-10 polluted countries: Fresh insights from quantile-onquantile regression approach. Renewable Energy 150:670–690. https://doi.org/10.1016/j.renene.2019.12.149

Stamford L, Azapagic A (2018) Environmental Impacts of Photovoltaics: The Effects of Technological Improvements and Transfer of Manufacturing from Europe to China. Energ Technol 6(6):1148–1160. https://doi.org/10.1002/ente.201800037

Stern DI (2004) The rise and fall of the environmental Kuznets curve. World Dev 32(8):1419–1439

Stern DI, Common MS, Barbier EB (1996) Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. World Dev 24(7):1151–1160

Su ZW, Umar M, Kirikkaleli D, Adebayo TS (2021) Role of political risk to achieve carbon neutrality: evidence from Brazil. J Environ Manag 298:113463

Suki NM, Sharif A, Afshan S, Suki NM (2020) Revisiting the environmental Kuznets curve in Malaysia: the role of globalization in sustainable environment. J Clean Prod 264:121669

Sultana N, Rahman MM, Khanam R (2022) Environmental kuznets curve and causal links between environmental degradation and selected socioeconomic indicators in Bangladesh. Environ Dev Sustain 24:426–5450. https://doi.org/10.1007/s10668-021-01665-w

Sun Y, Gao P, Raza SA, Shah N, Sharif A (2023) The asymmetric effects of oil price shocks on the world food prices: Fresh evidence from quantile-on-quantile regression approach. Energy 270:126812

Syed QR, Bouri E (2022) Impact of economic policy uncertainty on CO_2 emissions in the US: Evidence from bootstrap ARDL approach. J Public Aff 22(3):e2595

Tabachnick BG, Fidell LS (2013) Using Multivariate Statistics, 6th edn. Pearson, Boston, MA

Tamazian A, Rao BB (2010) Do economic, financial and ınstitutional developments matter for environmental degradation? Evidence from Transitional Economies. Energy Economics 32(1):137–145. https://doi.org/10.1016/j.eneco.2009.04.004

Unver M, Doğru B (2015) The Determinants of Economic Fragility: Case of The Fragile Five Countries. Akdeniz İ.İ.B.F. Dergisi 2015(31):1–24

Vo, DH., Nguyen, NT., Vo, AT., Ho, CM,. &Nguyen, TC. (2021). Does the Kuznets curve apply for financial development and environmental degradation in the Asia-Pacific region? Heliyon, 7(4), https://doi.org/10.1016/j.heliyon.2021.e06708

Vu TV, Huang DC (2020) Economic development, globalization, political risk and CO_2 emission: the case of Vietnam. J Asian Financ Econ Bus 7(12):21–31

Wang YC (2013) Functional sensitivity of testing the environmental Kuznets curve hypothesis. Resource Energy Economics 35(4):451–466

Wang ZH, Yin FC, Zhang YX, Zhang X (2012) An empirical researchs on the influencing factors of regional CO_2 emissions: evidence from Beijing city, China. Appl Energy 100:277–284

Wang P, Wu WS, Zhu BZ, Wei YM (2013) Examining the impact factors of energy- related CO_2 emissions using the STIRPAT model in Guangdong Province. China Appl Energy 106:65–71

Wang XY, Li G, Malik S, Anwar A (2022a) Impact of COVID-19 on achieving the goal of sustainable development: E-learning and educational productivity. Economic Research-Ekonomska Istraživanja 35(1):1950–1966

Wang X, Yan L, Zhao X (2022b) Tackling the ecological footprint in china through energy consumption, economic growth and CO_2 emission: an ARDL approach. Qual Quant 56(2):511–531

Weimin Z, Sibt-e-Ali M, Tariq M, Dagar V, Khan MK (2022) Globalization toward environmental sustainability and electricity consumption to environmental degradation: does EKC inverted U-shaped hypothesis exist between squared economic growth and CO_2 emissions in top globalized economies. Environ Sci Pollut Res 29(40):59974–59984

Wen J, Mughal N, Zhao J, Shabbir MS, Niedbała G, Jain V, Anwar A (2021) Does globalization matter for environmental degradation? Nexus among energy consumption, economic growth, and carbon dioxide emission. Energy Policy 153:112230

Wen Y, Shabbir MS, Haseeb M, Kamal M, Anwar A, Khan MF, Malik S (2022) The dynamic effect of information and communication technology and renewable energy on CO2 emission: Fresh evidence from panel quantile regression. Front Environ Sci 10:1123. https://doi.org/10.3389/fenvs.2022.953035

Wolde-Rufael Y, Weldemeskel EM (2020) Environmental policy stringency, renewable energy consumption and CO_2 emissions: Panel cointegration analysis for BRIICTS countries. Int J Green Energy 17(10):568–582

Xinmin W, Hui P, Hafeez M, Aziz B, Akbar WM, Mirza MA (2020) The nexus of environmental degradation and technology innovation and adoption: an experience from dragon. Air Qual Atmos Health 13:1119–1126. https://doi.org/10.1007/s11869-020-00868-w

Yan C, Li H, Li Z (2022) Environmental pollution and economic growth: Evidence of SO2 emissions and GDP in China. Front Public Health 10:930780. https://doi.org/10.3389/fpubh.2022.930780

Yang R, Tang W, Zhang J (2021) Technology improvement strategy for green products under competition: The role of government subsidy. Eur J Oper Res 289(2):553–568. https://doi.org/10.1016/j.ejor.2020.07.030

Yeter F, Eroğlu İ, Kangal N, Çoban MN (2021) Ekonomik Büyüme, Enerji Tüketimi ve Çevresel Bozulma İlişkisi: Türk Cumhuriyetleri Üzerine Panel Veri Analizi. Türk Dünyası Araştırmaları 129(255):405–432

Zafar MW, Shahbaz M, Sinha A, Sengupta T, Qin Q (2020) How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. J Clean Prod 268:122149

Zhang S, Liu X (2019) The roles of international tourism and renewable energy in environment: New evidence from Asian countries. Renewable Energy 139:385–394. https://doi.org/10.1016/j.renene.2019.02.046

Zhang M, Abbasi KR, Inuwa N, Sinisi CI, Alvarado R, Ozturk I (2023) Does economic policy uncertainty, energy transition and ecological innovation affect environmental degradation in the United States? Economic Research-Ekonomska Istraživanja 36(2):2177698. https://doi.org/10.1080/1331677X.2023.2177698

Zhao B, Yang W (2020) Does financial development influence CO_2 emissions? A Chinese Province-Level Study. Energy 200:117523