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RESEARCH ARTICLE

The effect of gross domestic product, urbanization, trade openness, financial development, and renewable energy on CO_2 emission

Muhammad Suhrab[1] · Jahangeer Ahmed Soomro[1] · Saif Ullah[2] · Javeed Chavara[3]

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Abstract

The purpose of this study is to analyze the influence of GDP, urbanization, trade openness, financial development, and renewable energy consumption on CO_2 emissions in Pakistan using yearly time series data from 1985 to 2018. The study utilized the cointegration technique and Granger causality for empirical estimation. The results of the study indicated that urbanization, financial development, and trade openness upsurge CO_2 emission. Whereas using renewable energy resources is favorable for the environment and possesses negative relation with CO_2 emission. All variables possess long-run relation with Co_2 emission. Granger causality shows unidirectional causality from GDP and renewable energy to CO_2 emission. The study contains insight for policymakers in Pakistan with beneficial policy recommendations to work toward a sustainable green environment.

Keywords Gross domestic product · Trade openness · Renewable energy · Urbanization · CO_2 emissions

Introduction

Many global climate-energy initiatives now explicitly aim to achieve net-zero CO_2 emissions. The common characteristics and tradeoffs of energy systems across global scenarios at the point of net-zero CO_2 emissions have not yet been studied, even though considerable research has evaluated net-zero emissions routes. In the broader context of climate stability, the rate of global temperature rise is directly correlated with total CO_2 emissions, meaning that any increase in atmospheric CO_2 will result in more warming in the future (Rogeljet al. 2015). Given these factors and facts, it is a specific target to reach net-zero emissions. This is becoming a more prevalent objective for energy and emissions policymakers worldwide. Rapid and broad energy system transformation, including significant energy and material efficiency increases, extensive electrification of energy end uses, and carbon control, are essential to achieving this aim. Now, there are different policies and procedures or measures which can be adopted to overcome it (DeAngelo et al. 2021).

In light of this environment, energy analysts are increasingly examining the difficulties and potential associated with net-zero emissions energy systems, including in-depth studies of various energy services and technologies. Recent studies have looked at the energy system mitigation paths in integrated assessment model (IAM) scenarios that keep warming to below 1.5 °C, giving insight into potential changes to the energy-economy-land system.

The threat of global warming has increased awareness in all spheres of life by 60 percent to lessen the terrible scenario that faces the entire world. Human activity on the earth's surface, which results in environmental devastation, is the primary cause of climate change (Adedoyin and Bekun, 2020). Since global warming has become a problem, individual nations and the entire world are expected to prepare and act to mitigate it. Because of the serious climate change issue, domestic and international attention has been drawn to it (Alola et al.

Responsible Editor: Arshian Sharif

✉ Jahangeer Ahmed Soomro
jahangeerahmed1@gmail.com

Muhammad Suhrab
writetosohrab@gmail.com

Saif Ullah
saifullah_142@yahoo.com

Javeed Chavara
sp19msef0013@maju.edu.pk

[1] Business Administration Department, Ilma University, Karachi, Pakistan

[2] Department of Management, Technology and Information Systems, Ziauddin University, Karachi, Pakistan

[3] Muhammad Ali Jinnah University, Karachi, Pakistan

2019). The air is contaminated by the emissions of many energy sources, especially fossil fuels and other nonrenewable energy sources. They will harm the environment and the general public's health. Clean water sources and wetlands are also accessible to air pollutants, which harm or kill marine life and contaminate clean water. The average temperature of the earth's surface has increased, ice glaciers started melting, alarming not just humans but also our planet's weather and climate systems. All this situation enhances natural disasters and could destroy the world's climate. The annual GDP of countries will shrink to 2–4% by 2040 (Solomon et al. 2007).

Among other things taken into account, economic growth has been said to have a devastating effect on pollution. Many economic practices based on and geared toward economic growth contribute to the emissions of pollutants (Bekun and Agboola, 2019). Economic expansion, including economic activity from many industries (agricultural, petroleum, energy mining, and manufacturing), all operate as pollution and CO_2 triggers (Udemba 2020).

Adebayo et al. (2021a, b) and Kirikkaleli et al. (2022) demonstrate that energy use and economic expansion are the primary causes of environmental degradation in many countries and locations. Zhang et al. (2021) study concluded that using energy from nonrenewable sources produces more CO_2, which reduces the viability of the ecosystem. The positive correlation between the use of fossil fuels and economic growth suggests that GDP growth drives up energy use and CO_2 emissions, which supports this stance.

Pakistan has been one of the top 10 nations impacted by climate change during the past 20 years. Pakistan has been one of the top ten countries most affected by climate change in the past 20 years due to frequent natural disasters like floods, droughts, heat waves, and cyclones. According to a news release, Pakistan had an average climate risk score of 29.1 from 2000 to 2019, saw 173 catastrophic occurrences, had a $3.77 billion economic loss, and had 502.45 fatalities per year (https://www.thenews.com.pk/print/937671-pakistan-among-top-10-countries-affected-by-climate-change-in-last-20-).

Research objective

This research aimed to investigate.

- the impact of renewable energy (RE) on CO_2 emissions in Pakistan,
- the impact of consumption on CO_2 emissions in Pakistan,
- the impact of gross domestic product on CO_2 emissions in Pakistan,
- the impact of urbanization on CO_2 emissions in Pakistan,
- the impact of trade openness (TO) on CO_2 emissions in Pakistan, and
- the impact of financial development on CO_2 emissions in Pakistan.

Problem statement

Industrialization and increased consumption of the growing population collaterally damaged the environment slowly with the passage of time. Industries released harmful gasses into the atmosphere without proper treatment. Increased levels of CO_2 started to trap the heat within the hemisphere of the earth. Now, it has been watched that worldwide warming caused by CO_2 outflows is one reason for warm waves, extraordinary climate, increased floods, the yearly increase in average temperature, melting of ice glaciers, and rising sea level. At the start, no one peeped into the matter, but the voice from all over the world rose when this destruction reached to its maximum level. Now, all environmental agencies, governments, and researchers started digging out the causes of CO_2 emissions. The focus of all is a shift of industries toward green methods and green innovations, technology, sustainable environment, and boosting usage of renewable sources of energy to reduce the level of CO_2 in the atmosphere in future decades.

Literature review

Environmental Kuznets curve (EKC), which Kotroni (2020) analyzed, shows mixed results between environmental decadence and economic growth, which intrigued a scholar to look at it unexpectedly. This research states that every country undergoes industrialization, which overcomes agriculture and economy shift to the cities that create an inequality situation where the owner of the industries holds a major part of the income and the employee seems to have decreased in their income. Furthermore, Kuznets stated that inequality had followed an inverted "U" shape as it increased and then decreased again with increased income per capita. He stated initially that GDP (growth) is positively related to environmental pollution, and it causes environmental pollution until it reaches a reasonable point where it starts decreasing because of many changes from new investments in the pollution-free economy and clean industrialization. CO_2 frequently rises with the rise of economic activities.

Nasir and Rehman (2011) for Pakistan revealed a positive relationship between trade openness and CO_2 emissions in the long run. Salah-Uddin et al. (2016) studied the long-run relationship between trade openness, economic growth, energy consumption, and carbon emission in Sri Lanka between 1971 and 2006. The study confirmed a causal long-run relationship between economic growth and CO_2 emissions.

Isik et al. (2018) studied linear and nonlinear relationships between tourism demand, RE consumption, and GDP (growth). The annual data of 126 countries covering the period from 1995 to 2012 was utilized. Results of the study indicate that there

are 2-way cause-and-effect relationships between RE and GDP (growth) in countries like T-7 (51.59–66.11). One way called unidirectional causal relation exists from RE consumption to GDP (growth) in Spain (6.13) and exists from GDP (growth) to RE consumption in China (4.23), Turkey (5.96), and Germany (2.54) was found, further showing that there is a causal relation exist from tourist arrivals to GDP (growth) in the T-7 countries (31.26). Furthermore, this study investigates scientists and other policymakers who have frequently been working on developing RE alternatives and other sources to reduce the dependence on traditional energy sources because these sources reduce the negative impact on the environment.

Heydari et al. (2019) studied the relationship between renewable energy generation and CO_2 emissions. The data from Canada, Italy, and Iran is utilized from1980 to 2015. Cointegration, regression, and Granger causality tests were used in the study. The study's results confirmed that increased use of renewable energy reduces fossil fuel utilization, which increases carbon emissions. The finding of this study declared physical evidence to enhance the usage of renewable energy to overcome CO_2 emissions. Marques et al. (2018) empirically analyzed the dimensions of energy growth, the emission of CO_2, and how this affects the Australian environment by energy consumption. The study's focused variables were coal, oil energy sector, and CO_2. The study period covered from 1965 to 2015. The results indicated that the utilization of RE reduces fossil fuel usage, which in return reduces the emission of CO_2. The study implies that Australia should boost the proportion of RE and decrease the proportion of fossil fuels. Kwakwa and Alhassan (2018) conducted a study on Ghana. They found that hydro energy, waste energy, and combustible renewable reduce CO_2 emissions, while the generation of electricity from fossil fuels puts upward pressure on CO_2 emissions.

Wang and Dong (2019) found in 14 sub-Saharan African countries that environmental pollution can be reduced by renewable energy, while there is the opposite effect of nonrenewable energy. Bulut (2019) studied USA data to investigate the relationship between renewable energy and CO_2. The study found that RE has a negative relation with CO_2 emissions, which means that whenever the consumption of RE increases, it will decrease CO_2 emissions. Moorthy et al. (2019) analyzed some barriers that significantly impact RE development. They found that social and regulatory barriers are directly affecting the development of RE. Breaking these barriers will enable organizations to invest in developing new technologies that are less harmful to the environment and increase the usage of RE further with fewer tariff energy solutions available for local people. Zafar et al. (2019) revealed the variables which affect environmental quality. The study variables included globalization and financial development (OECD countries). The study covered the period from 1990 to 2014. Results showed stimulated relation of energy which consumed on CO_2. Financial development and environmental quality have been negatively associated with CO_2; environmental quality will decrease pollution when FD and environmental quality increase. Results endorsed that long-run cointegration exists, and a bidirectional relationship exists between energy consumption and CO_2. The study's conclusion shows that energy consumption (EC) is the main culprit in increasing pollution. Researchers recommended that policymakers increase the other energy sources, including wind, solar energy, biodiesel and green technology, to enhance environmental quality.

Chien et al. (2021) validated the EKC hypothesis and showed a positive relation between economic growth and CO_2 emission, while renewable energy and technological innovation possess a negative relation with CO_2 emission in the context of Pakistan. Namahoro et al. (2021) studied the long-run effects of energy consumption and economic growth on CO_2 emissions regionally and globally. The study found that extreme energy usage and economic growth promote CO_2 emission, but renewable energy affects CO_2 emission negatively. Godil et al. (2021) investigated the cause and effects of economic growth, technology innovation, and renewable energy in the transport sector on CO_2 emissions in China. The study results show that renewable energy consumption and innovation reduce CO_2 emission, but GDP has a positive relationship with CO_2 emission. In this case, trade is the main component of economic development.

Maheswaranathan and Bhavan (2022) examined the Sri Lankan trade and CO_2 emission relationship over the years, which shows a significant effect of trade on CO_2 emission because trade compels to produce at a massive level with high-level energy consumption. Uğurlu (2022) studies the impact of GDP per capita, renewable energy consumption, and urban population on CO_2 emission in the Visegrad countries and EU climate policies. The study concludes that GDP per capita and urban population have a positive relationship, while renewable energy consumption negatively impacts CO_2 emissions.

Research methodology

Data and variables

The study utilizes yearly time series data covering the period from 1985 to 2018 for six variables, gross domestic product (GDP), urbanization (UP), trade openness (TO), financial development (FD), renewable energy (RE), and carbon dioxide (CO_2), mined from WDI. Table 1 shows the variables statistics summary.

Table 1 Descriptive statistics

Variables	Obs	Mean	Std. dev	Min	Max
CO_2	34	0.7596	0.1272	0.5120	0.947
FD	34	23.2111	4.2190	15.3861	29.7861
GDP	34	4.5692	1.8772	1.0140	7.7060
RE	34	50.5244	4.1853	44.2760	58.090
TO	34	33.2455	3.5069	25.3060	38.9090
UP	34	33.0092	2.1129	29.3440	36.4420

Empirical model and method

The study's econometric model specification is as follows:

$$CO_{2t} = \alpha_{0t} + \beta_{1t}(FD) + \beta_{2t}(GDP) + \beta_{3t}(RE) + \beta_{4t}(TO) + \beta_{5t}(UP) + \varepsilon_t$$

where CO_2 is the per capita emission of carbon dioxide in metric tons; *FD* (private sector) is the development of institutions and markets, measured as a country-to-country credit provided to the private sector by the financial sector (% of GDP); *GDP* (growth) is the gross domestic product, calculated by adding exports and imports of goods, services, and productions measured as a significant share of GDP (growth); *RE* is the consumption of renewable energy produced from hydropower, solar, and wind (% of total final energy consumption); *TO* (trade openness) is the cross border trade calculated as a percentage of GDP; *UP* (urbanization) is the percentage of the population living in industrial cities and ε (error term).

Model hypothesis

H1: There is a significant impact of GDP (growth) on CO_2 emissions in Pakistan.
H2: There is a significant impact of financial development (private sector) on CO_2 emissions in Pakistan.
H3: There is a significant impact of the urban population on CO_2 emissions in Pakistan.
H4: There is a significant impact of trade openness on CO_2 emissions in Pakistan.
H5: There is a significant impact of renewable energy on CO_2emissions in Pakistan.

Results

Unit root analysis

The first variable's stationary properties were tested using an augmented Dickey-Fuller (ADF) unit root test because time series data mostly contain unit root problems, leading to bogus results. Thus, before moving to the next stage, the stationarity of variables at level or integrated orders must be carefully observed. The stationary level of variables decides the data analysis and method used at the next level (Table 2).

Table 2 Unit root test

Variables	At level	At first difference	Order of integration
CO_2	0.2782	0.0000	I(1)
FD	0.6175	0.0012	I(1)
GDP	0.0126	0.0000	I(1)
RE	0.7494	0.0001	I(1)
TO	0.0957	0.0000	I(1)
UP	0.7421	0.0000	I(1)

Regression analysis

The percentage of change in the dependent variable concerning per unit variation in the independent variable is called the regression coefficient. Regression analysis is used to determine the relationship of variables. It identifies one or more independent variables that keep a relationship with independent variables. Table 3 concludes the regression result summary of variables. The *t*-stat figures predict that FD (private sector), RE, TO, and UP have a significant effect on CO_2 emission, but these variables impact differently in terms of their signs. TO, FD (private sector), and UP have positive effects on CO_2 emission, which concludes that any upsurge in these variables will increase CO_2 emissions.

On the other hand, when we analyze the result of RE and GDP, both have negative coefficients, which means adverse effects on CO_2 emissions. These results validate if there is a one-unit increase in RE, it will decrease the CO_2 emission with the same coefficient defined. Furthermore, Table 3 shows that GDP (growth) insignificantly affects CO_2 emissions. The possible reason behind that the GDP of Pakistan is unsustainable and it also faces several fluctuations. Moreover, there is also a major contribution of agriculture to the GDP of Pakistan. The findings demonstrate that the CO_2 emission will increase by 0.0056 units with a one-unit increase in FD (private sector). On the other hand, a one-unit increase in RE will decrease CO_2 emissions by 0.0093 units. The reason behind such results is that natural energy resource positively and significantly influences the ecological footprint.

Further results show that the emission of CO_2 will increase by 0.0068 units with a one-unit increase TO. A single unit increase in UP will increase CO_2 emission by 0.0531 units. As urban areas are industrial hubs, the increase in population in urban areas will increase the demand for transportation. In Pakistan, all transportation channels utilize fossil fuels and are a big source of CO_2 emissions. Furthermore, it is confirmed that independent variables have a jointly significant effect on CO_2 emission

Table 3 Time series regression (fixed effects)

Variable	Coefficient	T-statistics	Prob
FD	0.0056	2.3229	0.0277
GDP	−0.0039	−1.4364	0.1620
RE	−0.0093	−1.9841	0.0571
TO	0.0068	3.6355	0.0011
UP	0.0531	4.6331	0.0001
C	−0.8617	0.6591	N/A
Adj R^2	0.95589	Durbin-Watson stat	1.7332
F-statistic	143.9597	Prob (*F*-statistic)	0.0000

and that the overall model is significant (F-statist value 143.9597). The result of Adj. R^2 reflects that there are 95.589% chances that the CO_2 emission depends on FD, GDP, RE, TO, and UP. In other words, whenever CO_2 increases, there is a 95.5870% chance that these variables will be the reason for the increase.

Cointegration test

Johansen cointegration test has been applied to estimate long-run relationships among variables. Trace statistics is the main measurement tool for predicting cointegration. The results of Table 4 show that 5% critical values are less than trace values up to most 3*, which means there are three cointegrations among the variables. Results declared a long-run relationship between CO_2 emissions and their related determinant variables since it is confirmed that GDP (growth), UP, FD (private sector), RE, and TO impact CO_2 emissions significantly.

Granger causality analysis

To determine whether one time series predicts the other as caused by happening, the Granger causality test is considered a prominent one. Scholars prefer to use Granger causality analysis in determining the directions of dependent and independent. Lag one is applied for the analysis of causality. Jones (1989) considered ad hoc as one of the best methods for the statistical calculation of this analysis.

The findings of Granger causality are mentioned in Table 5, which reflect that a unidirectional and long-term relationship exists among GDP (growth) to CO_2 emission, RE to CO_2 emission, RE to FD (private sector), and UP to TO in the context of Pakistan.

Conclusion

CO_2 has been damaging the climates and environments around the globe. As we see, the earth's average temperature is rising yearly. This is because of an increase in the level of CO_2. CO_2 traps the heat and does not allow it to escape from the earth's surface. The study used prominent variables mentioned in the literature to check their impact on CO_2 levels in the context of Pakistan. The study found a significant positive relationship between financial development, trade openness, and urbanization with the emission of CO_2 because all the variables increase the utilization of fossil fuels in industries and transportation. The gross domestic product shows no significant relationship with the emission of CO_2 in the context of Pakistan. The possible reason may be the regular fluctuation in the GDP growth rate, and the GDP of Pakistan has a major chunk from the agriculture sector. At the same time, the use of renewable energy resources negatively impacts CO_2 emissions.

Future recommendation

- Research shows that FD (private sector) has not only a significant but also a positive relationship with the emission of CO_2, so this reveals that if more credit is given to the private sector in Pakistan, this will increase the emission of CO_2. There are many reasons behind this fact, some of which include because the industries in Pakistan do not utilize proper ways to eliminate wastage. Furthermore, the fuel and energy used by the industries in Pakistan are full of such components that cause the degradation of the environment. Similarly, many small companies operate in residential areas in Pakistan, so their waste is eliminated without proper treatment. The private sector must invest some part of their profit in improving the environment and adopting proper methods for the treatment of wastage and follow green environment practices.
- Trade openness and urbanization both put upward pressure on industries and transportation. In return, fossil fuel usage increases to meet the demand, resulting in the increased emission of CO_2. The government must bind industries to adopt environment-friendly methods and promote small industries, agriculture, and cattle farming in rural areas to reduce population pressure in cities.
- The RE consumption has a negative and significant relation with the emission of CO_2. Pakistan receives about 1 KW of solar energy per square meter of its landmass for 6–7 h per day. Solar panel installation in urban and rural

Table 4 Cointegration test

Null hypothesis	Trace	5% critical values	Prob	Max eigenvalue	5% critical values	Prob
None*	190.8982	117.7082	0.0000	73.70529	44.49720	0.0000
At most 1*	117.1929	88.80380	0.0001	43.44722	38.33101	0.0119
At most 2*	73.74567	63.87610	0.0059	36.04482	32.11832	0.0157
At most 3	37.70085	42.91525	0.1508	18.94104	25.82321	0.3093
At most 4	18.75981	25.87211	0.2952	15.94492	19.38704	0.1476
At most 5	2.814894	12.51798	0.8977	2.814894	12.51798	0.8977

Table 5 Granger causality test

Variables	LAG 1		LAG 2	
Null hypothesis	*F*-Statistic	Prob	*F*-Statistic	Prob
FD does not Granger cause CO_2	0.54324	0.4668	1.32138	0.2835
CO_2 does not Granger cause FD	1.37652	0.2499	1.51909	0.2370
GDP does not Granger cause CO_2	2.08425	0.1592	4.48672	0.0208
CO_2 does not Granger cause GDP	0.82913	0..3698	1.28894	0.2920
RE does not Granger cause CO_2	0.73825	0.3970	4.71458	0.0175
CO_2 does not Granger cause RE	5.09561	0.0314	2.31439	0.1181
TO does not Granger cause CO_2	0.00053	0.9818	1.06789	0.3578
CO_2 does not Granger cause TO	2.51968	0.1229	1.43712	0.2552
UP does not Granger cause CO_2	0.32807	0.5711	0.67245	0.5188
CO_2 does not Granger cause UP	0.00647	0.9364	0.31605	0.7317
GDP does not Granger cause FD	4.08179	0.0524	1.25573	0.3010
FD does not Granger cause GDP	0.11719	0.7345	0.94695	0.4004
RE does not Granger cause FD	1.05986	0.3115	5.54968	0.0096
FD does not Granger cause RE	0.06133	0.8061	0.85731	0.4355
TO does not Granger cause FD	0.58109	0.4518	0.66119	0.5244
FD does not Granger cause TO	3.37449	0.0761	1.64424	0.2119
UP does not Granger cause FD	1.20376	0.2813	1.34070	0.2785
FD does not Granger cause UP	0.22895	0.6358	0.07395	0.9289
RE does not Granger cause GDP	0.50293	0.4837	0.88713	0.4235
GDP does not Granger cause RE	0.31824	0.5769	1.09592	0.3486
TO does not Granger cause GDP	1.13620	0.2950	0.52530	0.5973
GDP does not Granger cause TO	5.81160	0.0223	2.97311	0.0681
UP does not Granger cause GDP	0.01236	0.9122	0.09660	0.9082
GDP does not Granger cause UP	0.38885	0.5376	1.67125	0.2069
TO does not Granger cause RE	0.50124	0.4844	0.65239	0.5244
RE does not Granger cause TO	3.60147	0.0674	1.78632	0.1868
UP does not Granger cause RE	2.54504	0.1211	1.33806	0.2792
RE does not Granger cause UP	0.16294	0.6893	1.16688	0.3265
UP does not Granger cause TO	6.39883	0.0169	4.03334	0.0293
TO does not Granger cause UP	0.04916	0.8260	0.04110	0.9598

areas is suggested to reduce pressure from fossil fuel usage. Hydro energy, wind energy, and biomass energy are also useful in the same regard.

Future researches

In the future, the research is advised to incorporate some variables like an intention to use CO_2, strict regulations and quality control, and strict penalties for the violation. Furthermore, the context can be more precise if researchers use other countries that reduce CO_2 by implementing such restrictions.

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Data availability The data file is also uploaded after the "Reference" section.

Declarations

Ethical approval The manuscript is not submitted to more any other journal nor published before. The manuscript is only submitted to Environmental Science and Pollution Research for publication process by the consent and approval of all authors.

Moreover, the manuscript utilized secondary data, and the data is collected from reliable sources.

Consent to participate All the authors are willing to participate for the goodwill of the journal and are bound to all policies of the journal.

Consent for publication All authors, namely Muhammad Suhrab, Jahangeer Ahmed Soomro, Dr. Saif Ullah, and Javeed Chavara, hereby show consent and allow the Journal Environmental Science and Pollution Research to process and publish the manuscript.

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References

Adebayo TS, Akinsola GD, Odugbesan JA, Olanrewaju VO (2021a) Determinants of environmental degradation in Thailand: empirical evidence from ARDL and wavelet coherence approaches. Pollution 7(1):181–196

Adebayo TS, Awosusi AA, Kirikkaleli D, Akinsola GD, Mwamba MN (2021b) Can CO_2 emissions and energy consumption determine the economic performance of South Korea? A time series analysis. Environ Sci Pollut Res 28(29):38969–38984

Adedoyin FF, Bekun FV (2020) Modelling the interaction between tourism, energy consumption, pollutant emissions and urbanization: renewed evidence from panel VAR. Environ Sci Pollut Res 27(31):38881–38900

Alola AA, Bekun FV, Sarkodie SA (2019) Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. Sci Total Environ 685:702–709

Bekun FV, Agboola MO (2019) Electricity consumption and economic growth nexus: evidence from Maki cointegration. Eng Econ 30(1):14–23

Bulut U (2019) Testing environmental Kuznets curve for the USA under a regime shift: the role of renewable energy. Environ Sci Pollut Res 26(14):14562–14569

Chien F, Ajaz T, Andlib Z, Chau KY, Ahmad P, Sharif A (2021) The role of technology innovation, renewable energy and globalization in reducing environmental degradation in Pakistan: a step towards sustainable environment. Renew Energy 177:308–317

DeAngelo J, Azevedo I, Bistline J, Clarke L, Luderer G, Byers E, Davis SJ (2021) Energy systems in scenarios at net-zero CO_2 emissions. Nat Commun 12(1):1–10

Godil DI, Yu Z, Sharif A, Usman R, Khan SAR (2021) Investigate the role of technology innovation and renewable energy in reducing transport sector CO_2 emission in China: a path toward sustainable development. Sustain Dev 29(4):694–707

Heydari A, Garcia DA, Keynia F, Bisegna F & De Santoli L (2019) Renewable energies generation and carbon dioxide emission forecasting in microgrids and national grids using GRNN-GWO methodology. Energy Proc 159:154–159

Isik C, Dogru T, Turk ES (2018) A nexus of linear and non-linear relationships between tourism demand, renewable energy consumption, and economic growth: Theory and evidence. Int J Tour Res 20(1):38–49

Jones JD (1989) A comparison of lag–length selection techniques in tests of Granger causality between money growth and inflation: evidence for the US, 1959–86. Appl Econ 21(6):809–822

Kirikkaleli D, Shah MI, Adebayo TS, Altuntaş M (2022) Does political risk spur environmental issues in China?.Environ Sci Pollut Res 1–11

Kotroni E (2020) Environmental Kuznets Curve in Greece in the period 1960-2014. 670216917

Kwakwa PA, Alhassan H (2018) The effect of energy and urbanisation on carbon dioxide emissions: evidence from Ghana. OPEC Energy Rev 42(4):301–330

Maheswaranathan S, Bhavan T (2022) Does a long-run relationship exist between trade openness and carbon dioxide emissions in Sri Lanka? Asian Dev Policy Rev 10(3):165–173

Marques AC, Fuinhas JA, Leal PA (2018) The impact of economic growth on CO_2 emissions in Australia: the environmental Kuznets curve and the decoupling index. Environ Sci Pollut Res 25(27):27283–27296

Moorthy K, Patwa N, Gupta Y (2019) Breaking barriers in deployment of renewable energy. Heliyon 5(1):e01166

Namahoro JP, Wu Q, Zhou N, Xue S (2021) Impact of energy intensity, renewable energy, and economic growth on CO_2 emissions: evidence from Africa across regions and income levels. Renew Sustain Energy Rev 147:111233

Nasir M, Rehman FU (2011) Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 39(3):1857–1864

Rogelj J, Schaeffer M, Meinshausen M, Knutti R, Alcamo J, Riahi K, Hare W (2015) Zero emission targets as long-term global goals for climate protection. Environ Res Lett 10(10):105007

Solomon S, Manning M, Marquis M, Qin D (2007) Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC (Vol. 4). Cambridge University Press

Uddin MGS, Bidisha SH, Ozturk I (2016) Carbon emissions, energy consumption, and economic growth relationship in Sri Lanka. Energy Sources Part B 11(3):282–287

Udemba EN (2020) A sustainable study of economic growth and development amidst ecological footprint: new insight from Nigerian Perspective. Sci Total Environ 732:139270

Uğurlu E (2022) Impacts of renewable energy on CO_2 emission: evidence from the Visegrad group countries. Politics Cent Eur 18(2):295–315

Wang J, Dong K (2019) What drives environmental degradation? Evidence from 14 Sub-Saharan African countries. Sci Total Environ 656:165–173

Zafar MW, Saud S, Hou F (2019) The impact of globalization and financial development on environmental quality: evidence from selected countries in the Organization for Economic Co-operation and Development (OECD). Environ Sci Pollut Res 26(13):13246–13262

Zhang L, Li Z, Kirikkaleli D, Adebayo TS, Adeshola I & Akinsola GD (2021) Modeling CO2 emissions in Malaysia: an application of Maki cointegration and wavelet coherence tests. Environ Sci Pollut Res 28(20):26030–26044