Environmental Science and Pollution Research (2021) 28:53520–53532
https://doi.org/10.1007/s11356-021-14537-7

RESEARCH ARTICLE

An asymmetrical analysis to explore the dynamic impacts of CO_2 emission to renewable energy, expenditures, foreign direct investment, and trade in Pakistan

Abdul Rehman[1] · Hengyun Ma[1] · Munir Ahmad[2] · Ilhan Ozturk[3,4,5] · Cem Işık[6]

Received: 8 April 2021 / Accepted: 18 May 2021 / Published online: 25 May 2021

Abstract

Carbon dioxide emission and GHGs are associated with fossil fuels which have adverse effects on the environment. The key intention of this paper was to determine the asymmetric effect of CO_2 emission on expenditures, trade, FDI, and renewable energy consumption in Pakistan. An asymmetrical technique (nonlinear autoregressive distributed lag) was employed to validate the constructive and adverse relation among variables. Furthermore, the Granger causality test was also used to verify the unidirectional association amid variables. Study outcomes revealed that the adverse shocks of renewable energy consumption exposed expressively to upsurge CO_2 emission in the short-run dynamics. Conversely, constructive shocks of renewable energy consumption display an adversative association with CO_2 emission. Furthermore, the decreasing trend in foreign direct investment tends to impede the detrimental effects of CO_2 emission. Additionally, the variable expenditures also create the non-eco-friendly impacts and manifest the positive linkage through CO_2 emission. Trade possesses statistically insignificant linkage with environmental degradation. The results also disclose that positive as well as negative variations in the foreign direct investment expose to degrade the environmental eminence. Long-run results suggest the direct association between downward trend in renewable energy consumption and CO_2 emission signifying that the pollution level decreases, and the upward trend in renewable energy consumption, however, demonstrates insignificantly positive effects. The results also disclose that positive as well as negative variations in the FDI lead to degrade the CO_2 emission. Moreover, it is found that the expenditures soar the issue of pollution again in the long run. Finally, the consequence of trade on CO_2 emission is adverse, as the outcome suggests. In order to improve the environmental policies for sustainable growth, the study provides direction toward a sustainable environment by reducing carbon dioxide emission.

Keywords CO_2 emission · Foreign direct investment · Trade · Renewable energy · Expenditures

Responsible Editor: Philippe Garrigues

✉ Abdul Rehman
abdrehman@henau.edu.cn

Hengyun Ma
h.y.ma@163.com

Munir Ahmad
munirahmad@zju.edu.cn

Ilhan Ozturk
ilhanozturk@cag.edu.tr

Cem Işık
cemisik@anadolu.edu.tr

1 College of Economics and Management, Henan Agricultural University, Zhengzhou 450002, China

2 School of Economics, Zhejiang University, Hangzhou 310027, China

3 Faculty of Economics and Administrative Sciences, Cag University, 33800 Mersin, Turkey

4 Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

5 Department of Finance, Asia University, 500, Liufeng Rd., Wufeng, Taichung 41354, Taiwan

6 Faculty of Tourism, Anadolu University, Eskişehir, Turkey

Introduction

Decreasing the carbon dioxide emissions at global level has become a major policy priority in the worldwide efforts to reduce climate change's hazardous consequences. In the co-operation of environmental policies, trade-associated economic activities and foreign direct investment have no exception. The linkage amid environmental quality, economic progression, and CO_2 emission is a hot debate, and this focus is highly important for many academics, officials, and various emerging economies. It is a mystifying relationship that needs attention regarding the reduction of carbon dioxide emissions in any region. Emissions also increase as the income levels grow (Wasti and Zaidi 2020). In emerging economies, growth trend has lack of adequate investment in the capital and foreign direct investment plays a vital role. It not only promotes economic growth in developing countries by funding capital but also transfers state-of-the-art production technology, management skills, and expertise to enable those countries to increase productivity, modernize their economies, and promote innovation. Foreign direct investment also generates employment and stimulates the economy and competitiveness of developing countries which have the key drivers for rapid growth (Lee 2013; Fernandes and Paunov 2012).

Climate change has been caused by the usage in recent decades of polluted energy (fossil fuels). This has affected the conditions of people and nature. Unless greenhouse gas (GHG) emissions continue to grow, more heating and long-term variations will occur to increase the temperature. There are several issues about human health and environmental quality in relation to carbon dioxide emission growth levels (Alshehry and Belloumi 2017; Apergis and Payne 2015; Jebli 2016; Dahlmann et al. 2019; Rosenzweig et al. 2020). Therefore, the question has been raised whether greenhouse gas emissions or improved environmental quality has been caused by economic growth, energy use, and foreign investments. An understanding of this relationship is expected to help establish strategies to mitigate pollution. Moreover, some authors stressed the lack of important explanatory variables in traditional EKC (environmental Kuznets curve) estimations. Energy is a key element of this partnership which is usually omitted (Bölük and Mert 2015; Dogan and Seker 2016; Charfeddine and Khediri 2016; Gill et al. 2018; Zafar et al. 2019).

Greenhouse gas emissions are, as we know, the main cause of global warming. Such emissions are used as the leading environmental dilapidation indicators, although other gas emission indicators have been used in preceding studies. In recent opinions, carbon dioxide emission is considered the leading ecological pollution indicator (Narayan et al. 2016; Stern 2017; Tiba and Omri 2017; Balsalobre-Lorente et al. 2019). One goal is to protect the atmosphere and to prevent the environment from continuously deteriorating, because governments of all countries face enormous costs in consequence to ongoing issues of environmental dilapidation. The global warming issue is currently one of the most serious problems plaguing industrialized countries, emerging countries, and developing countries, as a result to an environmentally friendly decline. A number of studies indicate that the ingestion of ozone layers is a significant cause of warming worldwide and related to carbon dioxide emissions (Alam et al. 2012; Ali et al. 2015a, b; Farhani and Ozturk 2015). Various research studies have been done to demonstrate the CO_2 emission influence on energy consumption, agriculture, agricultural soils, urban agglomeration, energy importations, population growth, urbanization, human capital, sustainable development, climatic variation and forestry, natural resources, crop yield, temperature, irrigation, and income inequality (Ahmad et al. 2021a; Rehman et al. 2021a; Rehman et al. 2019; Wu et al. 2020; Ahmad et al. 2021b; Rehman et al. 2021b; Hussain and Rehman 2021; Rehman et al. 2021c; Alvarado et al. 2021a; Chishti et al. 2021; Rehman et al. 2021d; Alvarado et al. 2021b; Shindell et al. 2019; Rehman et al. 2020; Ridzuan et al. 2020), but the main objective of the current study was to examine the asymmetric effect of CO_2 emission to expenditures, FDI, trade, and renewable energy consumption in Pakistan. Data ranging from 1975 to 2017 was used and the variable stationarity was proved by employing three unit root tests. The asymmetrical technique (NARDL) was utilized to explore the linkage among study variables. Furthermore, causality test of Granger was also employed to check the variable unidirectional relation.

Literature review

Greenhouse gasses produce mainly economic activities by fossil fuel combustion. The biggest cause of greenhouse gasses is the carbon dioxide and its emission, which is associated to energy usage and considered imperative to economic activities regarding industrial consumption and production (Chang and Li 2019; De Jong et al. 2017). In order to confirm sustainable economic progression, continuous improvement in environmental quality is essential. Energy usage linkage with economic growth get priorities for a nation to the detriment of the environment are one of the significant variables linked to environmental degradation. Although this has been interpreted in assessing environmental pollution determinants, most studies only connect total consumption of energy and ecological pollution to economic growth, in particular CO_2 emissions which is not only clarified by energy utilization and development (Zhang 2011; Sadorsky 2014; Sak 2018; Hou et al. 2020).

A majority of emerging economies rely on strategies for foreign direct investment to support their fast-growing economies. Foreign direct investment has been encouraged by the emerging economies as a priority for growth in current spans. However, it has double inspiration on the atmosphere in the host country (Linh and Lin 2014; Zeng and Eastin 2012; Assa 2018; Saidi et al. 2018). In those countries that have fewer environmental laws, foreign direct investment is usually undertaken to reduce production costs. Manufacturing is also the source of foreign direct investment, and development thus impacts a country's economy in the prime time. The cause of environmental destruction is growing population and its density. Increase demand for electricity, diesel, industrial goods, and transport will continue to increase with the growing population (Mahmood and Chaudhary 2012; Abdouli and Hammami 2017).

Energy is an important source of renewable fuel and technology for home cooking, energy generation, power, light, and everyday business. To accomplish its economic activities, the industry needs more energy and uses resources as a contribution for extent output. Furthermore, the objective of energy is to meet the market economy supply and demand that officialize economic activities and make export resources more competitive and productive (Ali et al. 2015a, b; Anwar 2016; Appiah 2018). The flows of foreign direct investment have gotten attention intensely and increased throughout the world, especially from the last few decades. It is generally expected to increase the accumulation of capital and productivity and thus stimulate economic growth. It is not a coincidence that many developed economies are keen to draw further attention toward the foreign direct investment. Though, the upsurge in FDI influx has resulted in a debate over its possible environmental impacts (Chandran and Tang 2013; Bakhsh et al. 2017; Bokpin 2017).

The correlation amid environmental pollution and income has been influenced by the trade and foreign direct investment. Therefore, trade liberalization and FDI are possible generators of carbon emissions to facilitate decomposition exploration. Countries participating in the trade across the borders share the distribution of technology and access to renewable energy technologies would help with foreign trade. The transition of the technology to the host country is also supported by FDI. It is advised to contribute to the physical capital stock of foreign direct investment (Gozgor 2017; Rafindadi and Ozturk 2017; Jiang et al. 2018; Shahbaz et al. 2019; Abdo et al. 2020). The carbon emissions have become a major problem in international FDI agreements and sustainable environment as developed countries continue to grow (Blanco et al. 2013; Hakimi and Hamdi 2016).

The variation in the climate and sustainable development decreased temperature in the world and climate variation has led scientists and policymakers to concentrate on the causes of CO_2 emission. The importance of the environmental Kuznets curve (EKC) for the atmosphere was the subject of extensive exploration. Finally, the connection between economic growth and emissions from carbon dioxide is reversed. Economic development will create a more polluting world before hitting the maximum level of income; there will then be more increases in economic growth that will boost environmental sustainability (Baek 2015; Amri 2018; Mbarek et al. 2018; Adu and Denkyirah 2018). A negative and positive correlation is believed to be the linkage amid financial growth and energy strength. In this regard, the principal conviction is that the innovations in financial cooperation in banks, financial markets, and foreign investments have prompted an expansion of lending to allow businesses to fund energy-intense goods like cars and machinery and therefore upsurge the consumption of energy and also adversely affect the environment by the pollution caused by air and water (Chang 2015; Phong 2019; Saud and Chen 2018). Developing countries need capital to improve their industrial and economic sectors in order to boost the productivity factor.

Methodology and data sources

The major source of time series data is WDI (https://data.worldbank.org/country/PK) which varies from 1975 to 2017, and the key variables of this analysis are CO_2 emission, expenditures, foreign direct investment, trade, and renewable

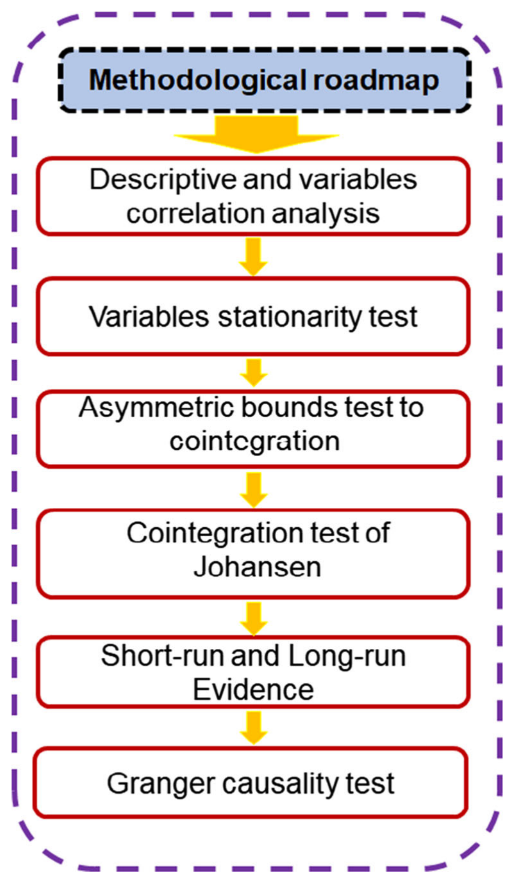


Fig. 1 Methodological roadmap of the study

Table 1 Descriptive analysis

	CO_2e	RNEWC	FDI	EXP	TR
Mean	11.28628	3.964802	− 3.812823	4.470680	3.530894
Median	11.45580	3.954503	− 3.678683	4.457998	3.562559
Maximum	12.13631	4.141734	− 2.232602	4.544046	3.661238
Minimum	10.03618	3.765787	− 7.297967	4.411444	3.231051
Std. dev.	0.659085	0.114097	1.043524	0.038986	0.108049
Skewness	− 0.461005	− 0.080211	− 1.383016	0.243402	− 1.033998
Kurtosis	1.968550	1.659708	5.179593	1.862869	3.651522
Jarque-Bera	3.429238	3.264626	22.21945	2.741331	8.422777
Probability	0.180032	0.195477	0.000015	0.253938	0.014826
Sum	485.3101	170.4865	− 163.9514	192.2393	151.8284
Sum sq. dev.	18.24450	0.546760	45.73559	0.063838	0.490336

energy consumption. Figure 1 illustrates the methodological roadmap of this study.

Econometric model

The following econometric model was established to verify the variables' association including CO_2 emission, renewable energy utilization, expenditures, foreign investment, and trade in Pakistan:

$$CO_2e_t = f(RNEWC_t, FDI_t, EXP_t, TR_t) \quad (1)$$

We can also write Eq. (1) as:

$$CO_2e_t = \psi_0 + \psi_1 RNEWC_t + \psi_2 FDI_t + \psi_3 EXP_t + \psi_4 TR_t + \varepsilon_t \quad (2)$$

In Eq. (2), $RNEWC_t$ indicates renewable energy consumption, FDI_t shows foreign direct investment, EXP_t indicates the expenditures, and TR_t shows the trade. t is dimension of time, ε_t is the error term, and ψ_1-ψ_4 indicates the coefficients in the model.

In Eq. (2), the dependent variable is CO_2 emission, while expenditures, FDI, trade, and renewable energy consumption are the independent variables. Short- and long-run relation can be demonstrated in this study in subsequent to ARDL (autoregressive distributed lag) method introduced by Pesaran et al. (2001). The error correction representation of this methodology can be specified as:

$$\Delta CO_2e_t = \beta_0 + \sum_{d=1}^{p} \theta_d \Delta CO_2e_{t-d} + \sum_{d=0}^{P} \pi_d \Delta RNEWC_{t-d} + \sum_{d=0}^{P} \delta_d \Delta FDI_{t-d} + \sum_{d=0}^{P} \lambda_d EXP_{t-d} + \sum_{d=0}^{P} \tau_d TR_{t-d} + \vartheta_1 CO_2e_{t-1} + \vartheta_2 RNEWC_{t-1} + \vartheta_3 FDI_{t-1} + \vartheta_4 EXP_{t-1} + \vartheta_5 TR_{t-1} + \varepsilon_t \quad (3)$$

Equation (3) demonstrates the short- and long-run dynamics linkage among variables which is more suitable for new critical values of small samples than for most conventional reintegration processes and therefore, it has benefit. To confirm the long-term estimates, however, Pesaran et al. (2001) projected that F-test considers the common consequence among the integrated long-term variables. Once cointegration is clear, however, long-term pliability is explored by ϑ_2–ϑ_5 and regularized through ϑ_1.

Moreover, an asymmetric technique (NARDL) can be stated through the study of Shin et al. (2014) in directive to the decomposition of renewable energy consumption and FDI with their positive ($RNEWC^+_t$; FDI^+_t) and negative ($RNEWC^-_t$; FDI^-_t) mechanisms which are as follows:

Table 2 Correlation amid variables

	CO_2e	RNEWC	FDI	EXP	TR
CO_2e	1.000000	− 0.967276	0.158135	0.226336	− 0.668995
RNEWC	− 0.967276	1.000000	− 0.238762	− 0.286288	0.702450
FDI	0.158135	− 0.238762	1.000000	0.116860	− 0.141156
EXP	0.226336	− 0.286288	0.116860	1.000000	− 0.303253
TR	− 0.668995	0.702450	− 0.141156	− 0.303253	1.000000

$$RNEWC^{+}{}_{t} = \sum_{h=1}^{t} \Delta RNEWC^{+}{}_{t} = \sum_{h=1}^{t} \max\left(\Delta RNEWC^{+}{}_{t}, 0\right) \quad (4)$$

$$RNEWC^{-}{}_{t} = \sum_{h=1}^{t} \Delta RNEWC^{-}{}_{t} = \sum_{h=1}^{t} \min\left(\Delta RNEWC^{-}{}_{t}, 0\right) \quad (5)$$

$$FDI^{+}{}_{t} = \sum_{h=1}^{t} \Delta FDI^{+}{}_{t} = \sum_{h=1}^{t} \max\left(\Delta FDI^{+}{}_{t}, 0\right) \quad (6)$$

$$FDI^{-}{}_{t} = \sum_{h=1}^{t} \Delta FDI^{-}{}_{t} = \sum_{h=1}^{t} \min\left(\Delta FDI^{-}{}_{t}, 0\right) \quad (7)$$

The specification of the NARDL model can be specified by using Eqs. (4), (5), (6), and (7) positive and negative shocks. So Eq. (3) can be written as in asymmetric model as:

$$\begin{aligned}\Delta CO_2e_t = {} & \beta_0 + \sum_{d=1}^{P} \theta_d \Delta CO_2e_{t-d} + \sum_{d=0}^{P} \psi_d \Delta RNEWC^{+}{}_{t-d} \\ & + \sum_{d=0}^{P} \pi_d \Delta RNEWC^{-}{}_{t-d} + \sum_{d=0}^{P} \delta_d \Delta FDI^{+}{}_{t-d} \\ & + \sum_{d=0}^{P} \eta_d \Delta FDI^{-}{}_{t-d} + \sum_{d=0}^{P} \lambda_d EXP_{t-d} \\ & + \sum_{d=0}^{P} \tau_d TR_{t-d} + \vartheta_1 CO_2e_{t-1} + \vartheta_2 RNEWC^{+}{}_{t-1} \\ & + \vartheta_3 RNEWC^{-}{}_{t-1} + \vartheta_4 FDI^{+}{}_{t-1} + \vartheta_5 FDI^{-}{}_{t-1} \\ & + \vartheta_6 EXP_{t-1} + \vartheta_7 TR_{t-1} + \varepsilon_t \quad (8)\end{aligned}$$

Equation (8) demonstrates the NARDL model specification. Besides that, the dynamics of short-run asymmetries include the Wald measure, which was also used as ($\sum\psi_{2d} \neq \sum\pi_{3d}$ and $\sum\delta_{4d} \neq \sum\eta_{5d}$) and for long-run asymmetries as ($^{\vartheta_2^{+}}/_{\vartheta_1} \neq {}^{\vartheta_3^{-}}/_{\vartheta_1}$ and $^{\vartheta_4^{+}}/_{\vartheta_1} \neq {}^{\vartheta_5^{-}}/_{\vartheta_1}$). The representation of ECM (error correction model) can be as follows:

$$\begin{aligned}\Delta CO_2e_t = {} & a_0 + \sum_{f=1}^{k} \theta_1 \Delta CO_2e_{t-1} + \sum_{f=0}^{k} \theta_2 \Delta RNEWC^{+}{}_{t-1} \\ & + \sum_{f=0}^{k} \theta_3 \Delta RNEWC^{-}{}_{t-1} + \sum_{f=0}^{k} \theta_4 \Delta FDI^{+}{}_{t-1} \\ & + \sum_{f=0}^{k} \theta_5 \Delta FDI^{-}{}_{t-1} + \sum_{f=0}^{k} \theta_6 EXP_{t-1} \\ & + \sum_{f=0}^{k} \theta_7 TR_{t-1} + \theta ECM_{t-1} + \varepsilon_t \quad (9)\end{aligned}$$

The nonlinear ARDL method also estimates the asymmetrical structural multiplier effects of CO_2 emission response to the RNEWC and FDI as follows:

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial CO_2e_{t+j}}{\partial RNEWC_j^{+}}, \quad m_h^{-} = \sum_{j=0}^{h} \frac{\partial CO_2e_{t+j}}{\partial RNEWC_j^{-}}$$

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial CO_2e_{t+j}}{\partial FDI_j^{+}} \; m_h^{-} = \sum_{j=0}^{h} \frac{\partial CO_2e_{t+j}}{\partial FDI_j^{-}} \; where\ h = 1, 2, 3\ldots.$$

$$And\ where\ m_h^{+} \to L_{mi^{+}}\ as\ h \to \infty, \text{and } m_h^{-} \to L_{mi^{-}}$$

The multiplier effect by estimating the unit shock of RNEWC and FDI shows a long-term balance adjustment.

Study outcomes and discussion

Descriptive and variable correlation analysis

Descriptive analysis results are reported in Table 1 with probability values. Additionally, correlations among variables are explored in Table 2. All variables including CO_2 emission, expenditures, FDI, trade, and renewable energy consumption are correlated.

Table 3 Unit root tests results

	CO_2e	RNEWC	FDI	EXP	TR
[ADF]					
I(0)	− 3.0578**	− 0.2383	− 4.1463***	− 1.7988	− 1.2086
I(1)	− 2.7272***	− 6.5869***	− 8.7627***	− 7.0271***	− 7.6827***
[P-P]					
I(0)	− 3.3283**	− 0.1721	− 4.1219***	− 1.7687	− 1.1030
I(1)	− 6.3284***	− 6.6013***	− 19.0816***	− 7.0823***	− 7.6801***
[KPSS]					
I(0)	0.8073***	0.8201***	0.2250	0.1929	0.7007**
I(1)	0.5204**	-	0.1219*	0.1336*	-

***, **, and * demonstrate that the series are stationary at 10%, 5%, and 1% respectively

Table 4 Asymmetric bounds test to cointegration consequences

Model	F-stat value	Values of critical bounds			Decision
CO_2e/(RNEWC, FDI, EXP, TR)	7.018130	Significance	Lower bounds	Upper bounds	Cointegration
		10%	2.12	3.23	
		5%	2.45	3.61	
		2.5%	2.75	3.99	
		1%	3.15	4.43	

Variables stationarity test

The results of the augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979), Phillips-Perron (P-P) (Phillips and Perron 1988), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski et al. 1992) unit root tests are depicted in Table 3. The attribution of the NARDL method is to achieve the successful results when all simulating variables are combined in the order of zero or one. Nevertheless, if every modeling variable is set to I(2), the drawback of asymmetric techniques is that it will yield inefficient findings.

Asymmetric bounds test to cointegration

An asymmetric technique was used to display the linkage of long-run connection amid variables and symmetry via bounds testing. Table 4 depicts the findings of the asymmetric bounds test to cointegration having F-statistic value of 7.018130 and level of significance at 10%, 5%, 2.5%, and 1% with lower and upper bound and get decision of cointegration.

Cointegration test of Johansen

The robustness among variables via long-run interferences can be determined by using the test of Johansen cointegration (Johansen and Juselius 1990) and consequences are interpreted in Table 5.

Long- and short-run evidence

Table 6 reveals the short- and long-run implications.

Table 6 illustrates the estimated short- and long-run outcomes of the NARDL technique. Focusing on the short-run estimates as Panel A demonstrates, the findings show that there is a large rise in carbon dioxide emissions due to negative energy usage shocks (RNEWC-). That suggests the carbon dioxide (CO2e) harmful effects have increased by 1.081% with a decrease of 1% in the use of renewable energy (RNEWC). The negative correlation of environmental emissions shows the optimistic shocks of green energy consumed, where 1% upsurge in the RNEWC insignificantly contracts the ration of carbon dioxide emission (CO_2e) by − 0.891%.

Furthermore, the decreasing trend in foreign direct investment (FDI) tends to impede the detrimental effects of carbon dioxide emission such that level of carbon emissions falls by − 0.037% as foreign direct investment squeezes by 1%. Conversely, the increasing trend in FDI shows the direct link with pollution, implying that expansion in the amount of FDI by 1% is accountable for boosting the level of carbon dioxide emission (CO_2e) by 0.040%. Additionally, we find that expenditures also create the non-eco-friendly impacts and manifest the positive association with the pollution. It indicates that the rise in the expenditure function by 1% results in polluting the environment by 1.316%. Besides, the variable of trade possesses the statistically insignificant relationship with the environmental degradation.

Do these short-run coefficients remain consistent in the long-run dynamics? Hence, we move toward the discussion

Table 5 Results of J cointegration test

Null hypothesis	TTS	0.05 CV	*P* values	Null hypothesis	MES	0.05 CV	*P* values
$r \leq 0$	68.79356	69.81889	0.0602	$r \leq 0$	32.83631	33.87687	0.0662
$r \leq 1$	35.95725	47.85613	0.3985	$r \leq 1$	20.27260	27.58434	0.3226
$r \leq 2$	15.68465	29.79707	0.7342	$r \leq 2$	9.862472	21.13162	0.7575
$r \leq 3$	5.822181	15.49471	0.7164	$r \leq 3$	4.770565	14.26460	0.7705
$r \leq 4$	1.051616	3.841465	0.3051	$r \leq 4$	1.051616	3.841465	0.3051

At 0.05 level, the max eigenvalue test displays no cointegration

Table 6 Short- and long-run outcomes

Variable	Coefficients	SE	T-statistics	*P* value
Panel A: Short-run coefficients				
D(RNEWC_NEG)	− 0.360793	0.309677	− 1.165064	0.2577
D(RNEWC_NEG(-1))	− 0.403413	0.432374	− 0.933018	0.3619
D(RNEWC_NEG(-2))	1.081650	0.399680	2.706292	0.0136
D(RNEWC_POS)	− 0.383185	0.637447	− 0.601124	0.5545
D(RNEWC_POS(-1))	− 0.891030	0.614335	− 1.450399	0.1625
D(FDI_NEG)	− 0.032032	0.007583	− 4.223903	0.0004
D(FDI_NEG(-1))	− 0.004326	0.009665	− 0.447582	0.6593
D(FDI_NEG(-2))	− 0.037065	0.009666	− 3.834468	0.0010
D(FDI_POS)	0.040884	0.009035	4.524848	0.0002
D(EXP)	− 0.344389	0.246007	− 1.399914	0.1769
D(EXP(-1))	1.316277	0.286024	4.601978	0.0002
D(TR)	0.035652	0.061084	0.583660	0.5660
Panel B: Long-run coefficients				
RNEWC_NEG	− 7.897465	3.792476	− 2.082403	0.0504
RNEWC_POS	1.755407	3.401693	0.516039	0.6115
FDI_NEG	0.339207	0.196577	1.725564	0.0998
FDI_POS	0.210202	0.098138	2.141896	0.0447
EXP	− 10.692380	6.119578	− 1.747241	0.0959
TR	0.274351	0.447233	0.613441	0.5465
C	57.438120	27.625152	2.079197	0.0507
Panel C: Diagnostics tests				
[R^2]	0.999221			
[Adj-R^2]	0.998520			
[CointEq(-1)]	− 0.129951	0.058891	− 2.206629	0.0392
[Value of F-test]	[7.018130]			
[Value of LM test]	1.70			
[Value of RESET test]	0.90			
[J-B test]	1.19			
[CUSUM]	[S]			
[CUSUMQ]	[S]			

of Panel B of long-run coefficients reported in Table 6. Fascinatingly, the consequences suggest the direct association between downward trend in renewable energy consumption and CO_2 emission, signifying that the pollution level decreases by − 7.897% on account of 1% decrease in deployment of renewables. The upward trend in renewable energy consumption, however, demonstrates insignificantly positive effects, indicating that 1% upsurge in renewable energy consumption is accountable for 1.755% upsurge in carbon dioxide emission (CO_2e). The results also disclose that positive as well as negative variations in the FDI lead to degrade the environmental quality. It means that 1% increase and decrease in the flows of foreign direct investment will intensify the ratio of CO_2 emission by 0.210% and 0.339%, respectively. Moreover, it is found that the expenditures, again in the long run, soar the issue of pollution such that CO_2 emission rises by 1.316% as the expenditure function enhances by 1%. Lastly, the effect of trade on CO_2 emission is insignificant, as the outcome suggests. Foreign direct investment inflows are now one of developing countries' key sources of external funding. But carbon emission and energy-intensive industries have moved from more stringent environmental inspection jurisdictions into weaker areas which lead to pollution paradises. In the challenges to achieve sustainable development targets, exports, distributes, and disseminations of foreign direct investment using polluting technology, products, and services to the developing countries have been the most critical challenge (Sarkodie and Strezov 2019; Jebli et al. 2019; Abban et al. 2020). The environmental dominance can also be assessed using FDI (foreign direct investment) influxes. There has been debate about the linkage amid FDI and environmental pollution, and pollution haven theory is the best

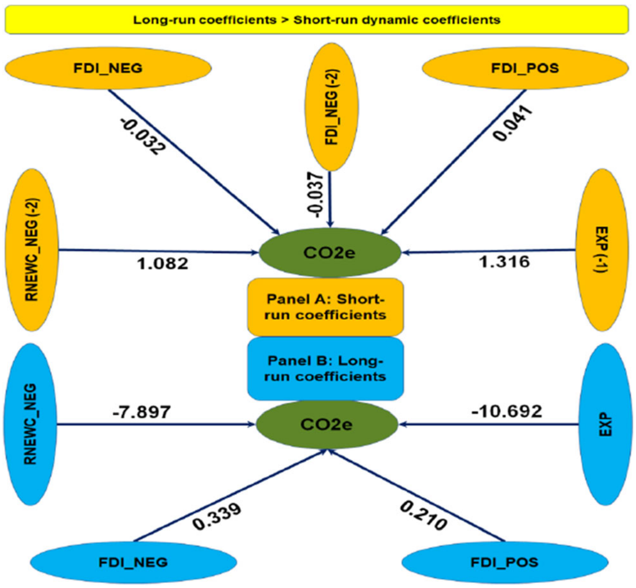


Fig. 2 Dynamic association of variables via short- and long-run analysis

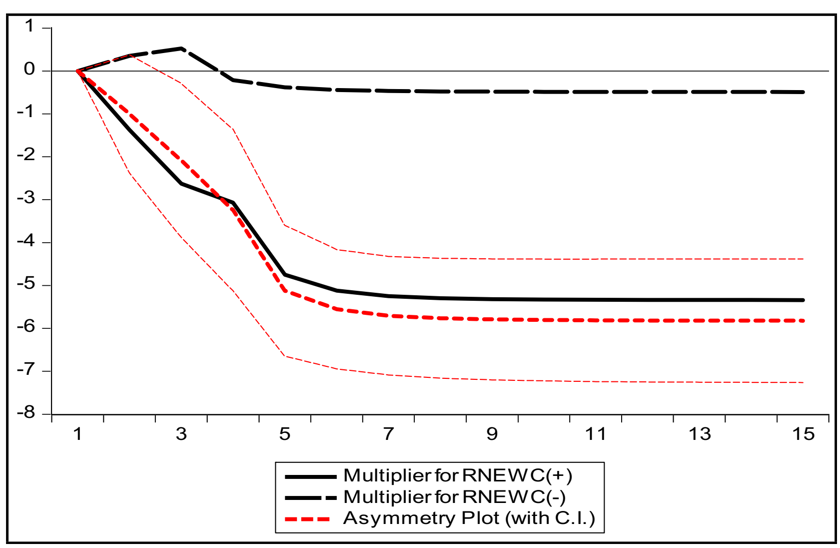
known to endorse the foreign direct investment relationship with environmental contamination (Yang et al. 2018; Saud et al. 2019).

FDI is considered an important component for renewable energy production. The technological progress of host country companies by technology transfer and technology spill overs can have a significant influence on FDI. It is effective in providing funding and technical aid for the renewable energy industry, since the production of renewables needs a large amount of capital and technology investment. Foreign direct investment also has an imperative role to boost the economy of any emerging economy, particularly emerging economies with advanced monetary markets (Azman-Saini and Law 2010; Liu et al. 2018; Chen et al. 2019). Over the past few decades, trade liberalization and FDI inflows have accelerated rapidly worldwide, and have also become an important environmental phenomenon (Seker et al. 2015; Omri et al. 2014).

The channels that impacted the level of financial growth and consumption of energy are direct, commercial, and wealthy. The straight impact is that customers can easily find resources to buy sustainable products and increase energy demand in an efficient financial intermediary environment. The impact on the market is driven by an increasing model of financial growth that gives businesses better access to financial resources. Financial growth enables companies to obtain cheaper resources to set up a new joint undertaking to increase demand for petroleum effectively. Trusts and families have a wealth effect on established capital markets (Çoban and Topcu 2013; Burakov and Freidin 2017; Salim et al. 2017). Rebalancing concentrations of greenhouse gasses from industrial activity is a major problem for states, policymakers, and experts. In developed countries, this problem is much more severe if standards and pollution management and control mechanisms are lacking. The other key argument expressed in the outcomes is that in fact the idea of conserving energy and saving energy is not. The fact that much of Pakistan's resources comes from fossil fuels is surprising. If no principles are utilized for energy conservation and savings, the same performance as increased pollution would be generated by the usage of more energy. That is an extraordinary chance to reach carbon neutrality and, as usual, a sustainable and optimistic economic growth–green sector revival. Access to new, fair, inexpensive, and clean energy is necessary in order to support the recovery of a green economy (Shah and Longsheng 2020; Shah 2020; Shah et al. 2021). Figure 2 clearly illustrates the short- and long-run dynamics among the study variables.

Beyond that, in the Panel C, some diagnostic tests are also used to demonstrate the robustness of the findings. The high values of R^2 and Adj-R^2 show the goodness of model which is fitted for the demonstration. Furthermore, the value of ECM

Fig. 3 Graph of $RNEWC^+$ and $RNEWC^-$



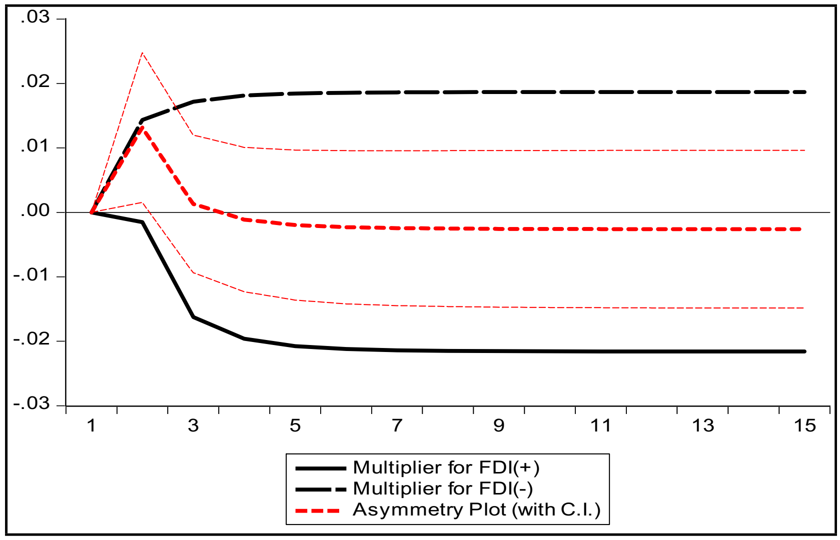


Fig. 4 Graph of FDI^+ and FDI^-

(error correction model) is −0.129 that is substantial at 5% significance level, which implies the slow convergence to long-run equilibrium. The LM test reports that the model is crippled with the problem of autocorrelation, while the R-RESET and J-Bera tests confirm the accurate specification of and normality in the estimated model, respectively. Finally, CUSUM and CUSUMQ tests assert the constancy of coefficients in the model. Figures 3 and 4 demonstrate the multiplier graph of $RNEWC^+$ and $RNEWC^-$ and multiplier graph of FDI^+ and FDI^-, respectively. Furthermore, Figs. 5 and 6 illustrate the CUSUM and CUSUM of square at 5% level of significance.

Causal association

To verify the unidirectional linkage amid CO_2 emission, renewable energy consumption, expenditures, foreign direct investment, and trade, the Granger causality method was used.

Table 7 results show that CO_2 emission did not show the causality to renewable energy consumption, expenditures, FDI, and TR. Similarly, RNEWC did not expose the causality linkage to CO_2 emission, FDI, EXP, and TR. The FDI also did not expose the causality connection to CO_2 emission, RNEWC, EXP, and TR. Furthermore, EXP did not display a causality linkage to CO_2 emission, RNEWC, TR, and FDI. TR also did not demonstrate a causality association to CO_2 emission, RNEWC, EXP, and FDI.

Conclusion and policy recommendations

The principal intention of this paper was to demonstrate the effect of CO_2 emission on expenditures, FDI, trade, and renewable energy consumption in Pakistan. Three unit root tests were applied to demonstrate the variable stationarity. The nonlinear autoregressive distributed lag (NARDL) method was

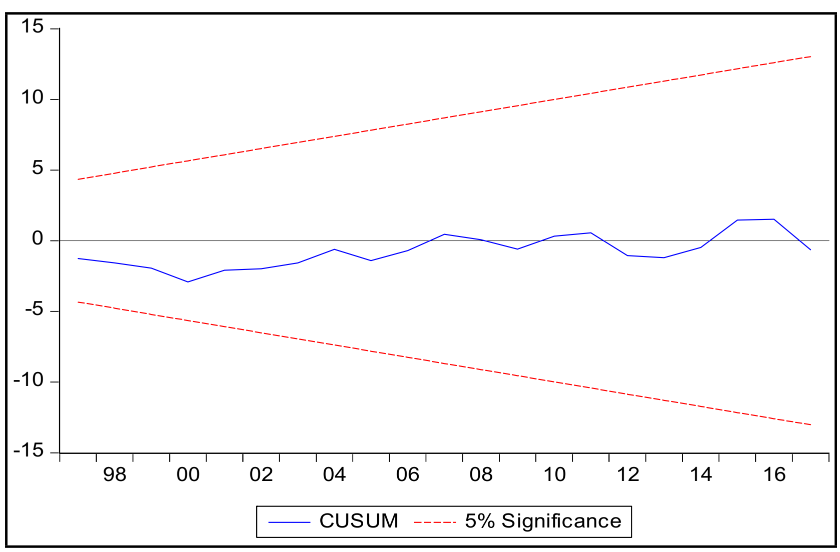


Fig. 5 CUSUM graph (5% significance level)

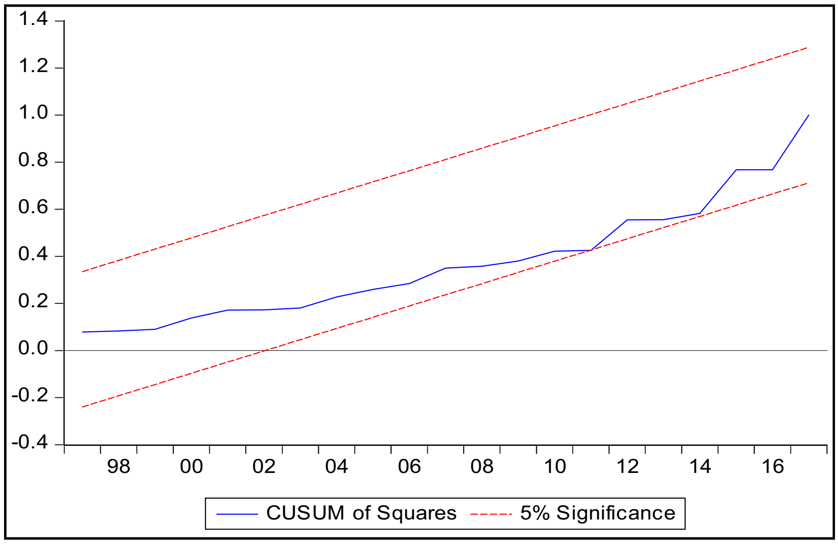


Fig. 6 CUSUM of squares graph (5% significance level)

employed to verify the dynamic relation among variables with short- and long-run analysis. Furthermore, a causality test was also employed to confirm the variable unidirectional causal association between variables. Study outcomes exposed that the deleterious shocks of renewable energy utilization display a suggestively upsurge of the CO_2 emissions in short-run dynamics. The constructive shock of renewable energy consumption exposes the adversative connection with the environmental pollution. Furthermore, the decreasing trend in foreign direct investment tends to impede the detrimental effects of carbon dioxide emission. Moreover, expenditures also create the non-eco-friendly impacts and manifest the constructive linkage with the CO_2 emission. The variable trade possesses the statistically insignificant connection with the environmental degradation. Results also disclose that positive as well as negative variations in the FDI lead to degrade the environmental quality. Similarly, the results of long run suggest the direct association between downward trend in the renewable energy consumption and CO_2 emission, signifying that pollution level decreases. The upward trend in the renewable energy consumption, however, demonstrates insignificantly positive effects. The results also reveal that positive as well as negative variations in FDI lead to degrade the pollution. The expenditures again demonstrate the issue of pollution in the long run and the trade influence on environmental pollution is also insignificant.

Table 7 Causal association among variables

Causality tests results

Null Hypothesis:	F-Statistic	Prob.
EXP did not expose the causality to CO_2e	1.35452	0.2709
CO_2e did not expose the causality to EXP	0.25807	0.7740
TR did not expose the causality to CO_2e	0.96261	0.3915
CO_2e did not expose the causality to TR	1.28339	0.2895
FDI did not expose the causality to CO_2e	0.05400	0.9475
CO_2e did not expose the causality to FDI	1.00868	0.3748
RNEWC did not expose the causality to CO_2e	5.08251	0.0114
CO_2e did not expose the causality to RNEWC	1.72968	0.1918
TR did not expose the causality to EXP	1.06477	0.3554
EXP did not expose the causality to TR	2.43154	0.1022
FDI did not expose the causality to EXP	3.15909	0.0544
EXP did not expose the causality to FDI	0.10197	0.9033
RNEWC did not expose the causality to EXP	2.94718	0.0653
EXP did not expose the causality to RNEWC	1.60001	0.2159
FDI did not expose the causality to TR	2.68957	0.0815
TR did not expose the causality to FDI	1.39883	0.2600
RNEWC did not expose the causality to TR	1.62601	0.2108
TR did not expose the causality to RNEWC	0.74351	0.4826
RNEWC did not expose the causality to FDI	1.61498	0.2130
FDI did not expose the causality to RNEWC	0.77716	0.4673

In order to improve the environmental policies for sustainable growth, the study pointed out the direction for a sustainable environment by reducing CO_2 emissions. FDI has a key role to upsurge the economy of Pakistan and technological development. Pakistan is belonging to those countries that have lack of corporeal capital, and overseas corporations can assist to improve the performance in order to enhance capital structure. It creates the opportunity of jobs to improve the living standards of community through management skills and advanced technology, and also brings the local economy in the competition of worldwide. The amendment of Pakistan's trade policy is aimed at attracting FDI into the country. Preferential trade taxes and reduction of tariff create a favorable place for foreigner investor in the country. Trade liberalization has accelerated economic growth, but it also causes environmental dilapidation, especially in the emerging economies. From the past few decades, the process of environmental degradation in developing countries has accelerated at an alarming rate. Due to variations in climate, Pakistan's economy has slowed down. CO_2 emission has direct linkage to climatic variations that reflect major changes in the weather conditions during a particular period.

Abbreviations *GHGs,* Greenhouse gasses; *FDI,* Foreign direct investment; *CO_2e,* Carbon dioxide emission; *NARDL,* Nonlinear autoregressive distributed lag; *EKC,* Environmental Kuznets curve; *WDI,* World Development Indicators; *RNEWC,* Renewable energy consumption; *EXP,* Expenditures; *TR,* Trade; *ARDL,* Autoregressive distributed lag; *ECM,* Error correction model; *ADF,* Augmented Dickey-Fuller; *P-P,* Phillips-Perron; *KPSS,* Kwiatkowski-Phillips-Schmidt-Shin

Author contribution AR conceived the study, collected the data, designed the econometric methodology, and write the original draft; IO and MA reviewed and edited the manuscript; HM and CI read and made suggestions to improve the quality of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Abban OJ, Wu J, Mensah IA (2020) Analysis on the nexus amid CO 2 emissions, energy intensity, economic growth, and foreign direct investment in Belt and Road economies: does the level of income matter? Environ Sci Pollut Res 27(10):11387–11402

Abdo AB, Li B, Zhang X, Lu J, Rasheed A (2020) Influence of FDI on environmental pollution in selected Arab countries: a spatial econometric analysis perspective. Environ Sci Pollut Res Int 27:28222–28246. https://doi.org/10.1007/s11356-020-08810-4

Abdouli M, Hammami S (2017) The impact of FDI inflows and environmental quality on economic growth: an empirical study for the MENA countries. J Knowl Econ 8(1):254–278

Adu DT, Denkyirah EK (2018) Economic growth and environmental pollution in West Africa: testing the environmental Kuznets curve hypothesis. Kasetsart Journal of Social Sciences:1–8. https://doi.org/10.1016/j.kjss.2017.12.008

Ahmad M, Rehman A, Shah SAA, Solangi YA, Chandio AA, Jabeen G (2021a) Stylized heterogeneous dynamic links among healthcare expenditures, land urbanization, and CO2 emissions across economic development levels. Sci Total Environ 753:142228

Ahmad M, Akram W, Ikram M, Shah AA, Rehman A, Chandio AA, Jabeen G (2021b) Estimating dynamic interactive linkages among urban agglomeration, economic performance, carbon emissions, and health expenditures across developmental disparities. Sustainable Production and Consumption 26:239–255

Alam MJ, Begum IA, Buysse J, Van Huylenbroeck G (2012) Energy consumption, carbon emissions and economic growth nexus in Bangladesh: cointegration and dynamic causality analysis. Energy Policy 45:217–225

Ali A, Khatoon S, Ather M, Akhtar N (2015a) Modeling energy consumption, carbon emission and economic growth: empirical analysis for Pakistan. Int J Energy Econ Policy 5(2)

Ali HS, Yusop ZB, Hook LS (2015b) Financial development and energy consumption nexus in Nigeria: an application of autoregressive distributed lag bound testing approach. Int J Energy Econ Policy 5(3): 816–821

Alshehry AS, Belloumi M (2017) Study of the environmental Kuznets curve for transport carbon dioxide emissions in Saudi Arabia. Renew Sust Energ Rev 75:1339–1347

Alvarado R, Deng Q, Tillaguango B, Méndez P, Bravo D, Chamba J, Alvarado-Lopez M, Ahmad M (2021a) Do economic development and human capital decrease non-renewable energy consumption? Evidence for OECD countries. Energy 215:119147

Alvarado R, Tillaguango B, López-Sánchez M, Ponce P, Işık C (2021b) Heterogeneous impact of natural resources on income inequality: the role of the shadow economy and human capital index. Economic Analysis and Policy 69:690–704

Amri F (2018) Carbon dioxide emissions, total factor productivity, ICT, trade, financial development, and energy consumption: testing environmental Kuznets curve hypothesis for Tunisia. Environ Sci Pollut Res 25(33):33691–33701

Anwar J (2016) Analysis of energy security, environmental emission and fuel import costs under energy import reduction targets: a case of Pakistan. Renew Sust Energ Rev 65:1065–1078

Apergis N, Payne JE (2015) Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. Energy Sources, Part B: Economics, Planning, and Policy 10(3):281–287

Appiah MO (2018) Investigating the multivariate Granger causality between energy consumption, economic growth and CO2 emissions in Ghana. Energy Policy 112:198–208

Assa BSK (2018) Foreign direct investment, bad governance and forest resources degradation: evidence in Sub-Saharan Africa. Econ Polit 35(1):107–125

Azman-Saini WNW, Law SH (2010) FDI and economic growth: new evidence on the role of financial markets. Econ Lett 107(2):211–213

Baek J (2015) Environmental Kuznets curve for CO2 emissions: the case of Arctic countries. Energy Econ 50:13–17

Bakhsh K, Rose S, Ali MF, Ahmad N, Shahbaz M (2017) Economic growth, CO2 emissions, renewable waste and FDI relation in Pakistan: new evidences from 3SLS. J Environ Manag 196:627–632

Balsalobre-Lorente D, Shahbaz M, Jabbour CJC, Driha OM (2019) The role of energy innovation and corruption in carbon emissions: evidence based on the EKC hypothesis. In Energy and Environmental Strategies in the Era of Globalization (pp. 271-304). Springer, Cham.

Blanco L, Gonzalez F, Ruiz I (2013) The impact of FDI on CO2 emissions in Latin America. Oxf Dev Stud 41(1):104–121

Bokpin GA (2017) Foreign direct investment and environmental sustainability in Africa: the role of institutions and governance. Res Int Bus Financ 39:239–247

Bölük G, Mert M (2015) The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach. Renew Sust Energ Rev 52:587–595

Burakov D, Freidin M (2017) Financial development, economic growth and renewable energy consumption in Russia: a vector error correction approach. Int J Energy Econ Policy 7(6):39–47

Chandran VGR, Tang CF (2013) The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies. Renew Sust Energ Rev 24:445–453

Chang SC (2015) Effects of financial developments and income on energy consumption. Int Rev Econ Financ 35:28–44

Chang SC, Li MH (2019) Impacts of foreign direct investment and economic development on carbon dioxide emissions across different population regimes. Environ Resour Econ 72(2):583–607

Charfeddine L, Khediri KB (2016) Financial development and environmental quality in UAE: cointegration with structural breaks. Renew Sust Energ Rev 55:1322–1335

Chen Y, Wang Z, Zhong Z (2019) CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renew Energy 131:208–216

Chishti MZ, Ahmad M, Rehman A, Khan MK (2021) Mitigations pathways towards sustainable development: assessing the influence of fiscal and monetary policies on carbon emissions in BRICS economies. J Clean Prod 292:126035

Çoban S, Topcu M (2013) The nexus between financial development and energy consumption in the EU: a dynamic panel data analysis. Energy Econ 39:81–88

Dahlmann F, Branicki L, Brammer S (2019) Managing carbon aspirations: the influence of corporate climate change targets on environmental performance. J Bus Ethics 158(1):1–24

De Jong S, Antonissen K, Hoefnagels R, Lonza L, Wang M, Faaij A, Junginger M (2017) Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production. Biotechnology for biofuels 10(1):64

Dickey DA, Fuller WA (1979) Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 74(366a):427–431

Dogan E, Seker F (2016) The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Sust Energ Rev 60:1074–1085

Farhani S, Ozturk I (2015) Causal relationship between CO 2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res 22(20):15663–15676

Fernandes AM, Paunov C (2012) Foreign direct investment in services and manufacturing productivity: evidence for Chile. J Dev Econ 97(2):305–321

Gill AR, Viswanathan KK, Hassan S (2018) A test of environmental Kuznets curve (EKC) for carbon emission and potential of renewable energy to reduce greenhouse gases (GHG) in Malaysia. Environ Dev Sustain 20(3):1103–1114

Gozgor G (2017) Does trade matter for carbon emissions in OECD countries? Evidence from a new trade openness measure. Environ Sci Pollut Res 24(36):27813–27821

Hakimi A, Hamdi H (2016) Trade liberalization, FDI inflows, environmental quality and economic growth: a comparative analysis between Tunisia and Morocco. Renew Sust Energ Rev 58:1445–1456

Hou J, Deng X, Springer CH, Teng F (2020) A global analysis of CO2 and non-CO2 GHG emissions embodied in trade with Belt and Road Initiative countries. Ecosystem Health and Sustainability:1761888

Hussain I, Rehman A (2021) Exploring the dynamic interaction of CO2 emission on population growth, foreign investment, and renewable energy by employing ARDL bounds testing approach. Environ Sci Pollut Res:1–11. https://doi.org/10.1007/s11356-021-13502-8

Jebli MB (2016) On the causal links between health indicator, output, combustible renewables and waste consumption, rail transport, and CO 2 emissions: the case of Tunisia. Environ Sci Pollut Res 23(16):16699–16715

Jebli MB, Youssef SB, Apergis N (2019) The dynamic linkage between renewable energy, tourism, CO 2 emissions, economic growth, foreign direct investment, and trade. Latin American Economic Review 28(1):1–19. https://doi.org/10.1186/s40503-019-0063-7

Jiang L, Zhou HF, Bai L, Zhou P (2018) Does foreign direct investment drive environmental degradation in China? An empirical study based on air quality index from a spatial perspective. J Clean Prod 176:864–872

Johansen S, Juselius K (1990) Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxf Bull Econ Stat 52(2):169–210

Kwiatkowski D, Phillips PC, Schmidt P, Shin Y (1992) Testing the null hypothesis of stationarity against the alternative of a unit root. J Econ 54(1-3):159–178

Lee JW (2013) The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. Energy Policy 55:483–489

Linh DH, Lin SM (2014) CO2 emissions, energy consumption, economic growth and FDI in Vietnam. Managing Global Transitions: International Research Journal 12(3)

Liu Q, Wang S, Zhang W, Zhan D, Li J (2018) Does foreign direct investment affect environmental pollution in China's cities? A spatial econometric perspective. Sci Total Environ 613:521–529

Mahmood H, Chaudhary AR (2012) FDI, population density and carbon dioxide emissions: a case study of Pakistan. Iranica Journal of Energy & Environment 3(4):354–360

Mbarek MB, Saidi K, Rahman MM (2018) Renewable and non-renewable energy consumption, environmental degradation and economic growth in Tunisia. Qual Quant 52(3):1105–1119

Narayan PK, Saboori B, Soleymani A (2016) Economic growth and carbon emissions. Econ Model 53:388–397

Omri A, Nguyen DK, Rault C (2014) Causal interactions between CO2 emissions, FDI, and economic growth: evidence from dynamic simultaneous-equation models. Econ Model 42:382–389

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326

Phillips PC, Perron P (1988) Testing for a unit root in time series regression. Biometrika 75(2):335–346

Phong LH (2019) Globalization, financial development, and environmental degradation in the presence of environmental Kuznets curve: evidence from ASEAN-5 countries. Int J Energy Econ Policy 9(2):40–50

Rafindadi AA, Ozturk I (2017) Dynamic effects of financial development, trade openness and economic growth on energy consumption: evidence from South Africa. Int J Energy Econ Policy 7(3):74–85

Rehman A, Ozturk I, Zhang D (2019) The causal connection between CO2 emissions and agricultural productivity in Pakistan: empirical evidence from an autoregressive distributed lag bounds testing approach. Appl Sci 9(8):1692

Rehman A, Ma H, Ozturk I (2020) Decoupling the climatic and carbon dioxide emission influence to maize crop production in Pakistan. Air Qual Atmos Health:1–13. https://doi.org/10.1007/s11869-020-00825-7

Rehman A, Ma H, Ozturk I, Murshed M, Dagar V (2021a) The dynamic impacts of CO2 emissions from different sources on Pakistan's economic progress: a roadmap to sustainable development. Environ Dev Sustain:1–24. https://doi.org/10.1007/s10668-021-01418-9

Rehman A, Ma H, Ozturk I (2021b) Do industrialization, energy importations, and economic progress influence carbon emission in Pakistan. Environ Sci Pollut Res:1–13. https://doi.org/10.1007/s11356-021-13916-4

Rehman A, Ma H, Chishti MZ, Ozturk I, Irfan M, Ahmad M (2021c) Asymmetric investigation to track the effect of urbanization, energy utilization, fossil fuel energy and CO 2 emission on economic efficiency in China: another outlook. Environ Sci Pollut Res 28(14):17319–17330

Rehman A, Ma H, Ahmad M, Irfan M, Traore O, Chandio AA (2021d) Towards environmental sustainability: devolving the influence of carbon dioxide emission to population growth, climate change, Forestry, livestock and crops production in Pakistan. Ecol Indic 125:107460

Ridzuan NHAM, Marwan NF, Khalid N, Ali MH, Tseng ML (2020) Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: evidence of the environmental Kuznets curve. Resour Conserv Recycl 160:104879

Rosenzweig C, Mbow C, Barioni LG, Benton TG, Herrero M, Krishnapillai M, Liwenga ET, Pradhan P, Rivera-Ferre MG, Sapkota T, Tubiello FN (2020) Climate change responses benefit from a global food system approach. Nature Food 1(2):94–97

Sadorsky P (2014) The effect of urbanization on CO2 emissions in emerging economies. Energy Econ 41:147–153

Saidi K, Mbarek MB, Amamri M (2018) Causal dynamics between energy consumption, ICT, FDI, and economic growth: case study of 13 MENA countries. J Knowl Econ 9(1):228–238

Sak R (2018) Gender differences in Turkish early childhood teachers' job satisfaction, job burnout and organizational cynicism. Early Childhood Educ J 46(6):643–653

Salim R, Yao Y, Chen G, Zhang L (2017) Can foreign direct investment harness energy consumption in China? A time series investigation. Energy Econ 66:43–53

Sarkodie SA, Strezov V (2019) Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Sci Total Environ 646:862–871

Saud S, Chen S (2018) An empirical analysis of financial development and energy demand: establishing the role of globalization. Environ Sci Pollut Res 25(24):24326–24337

Saud S, Chen S, Haseeb A (2019) Impact of financial development and economic growth on environmental quality: an empirical analysis from Belt and Road Initiative (BRI) countries. Environ Sci Pollut Res 26(3):2253–2269

Seker F, Ertugrul HM, Cetin M (2015) The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. Renew Sust Energ Rev 52:347–356

Shah SAA (2020) Feasibility study of renewable energy sources for developing the hydrogen economy in Pakistan. Int J Hydrog Energy 45(32):15841–15854

Shah SAA, Longsheng C (2020) New environmental performance index for measuring sector-wise environmental performance: a case study of major economic sectors in Pakistan. Environ Sci Pollut Res 27(33):41787–41802

Shah SAA, Longsheng C, Solangi YA, Ahmad M, Ali S (2021) Energy trilemma based prioritization of waste-to-energy technologies: implications for post-COVID-19 green economic recovery in Pakistan. J Clean Prod 284:124729

Shahbaz M, Gozgor G, Adom PK, Hammoudeh S (2019) The technical decomposition of carbon emissions and the concerns about FDI and trade openness effects in the United States. Int Econ 159:56–73

Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In Festschrift in honor of Peter Schmidt (pp. 281-314). Springer, New York, NY.

Shindell D, Faluvegi G, Kasibhatla P, Van Dingenen R (2019) Spatial patterns of crop yield change by emitted pollutant. Earth's Future 7(2):101–112

Stern DI (2017) The environmental Kuznets curve after 25 years. J Bioecon 19(1):7–28

Tiba S, Omri A (2017) Literature survey on the relationships between energy, environment and economic growth. Renew Sust Energ Rev 69:1129–1146

Wasti SKA, Zaidi SW (2020) An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: a case of Kuwait. Journal of Building Engineering 28: 101104

Wu W, Takahashi K, Zhou L, Jin S (2020) Income inequality and the distributional effects of elevated carbon dioxide on dietary nutrient deficiency. J Clean Prod:121606. https://doi.org/10.1016/j.jclepro.2020.121606

Yang J, Guo H, Liu B, Shi R, Zhang B, Ye W (2018) Environmental regulation and the Pollution Haven Hypothesis: do environmental regulation measures matter? J Clean Prod 202:993–1000

Zafar MW, Mirza FM, Zaidi SAH, Hou F (2019) The nexus of renewable and nonrenewable energy consumption, trade openness, and CO 2 emissions in the framework of EKC: evidence from emerging economies. Environ Sci Pollut Res 26(15):15162–15173

Zeng K, Eastin J (2012) Do developing countries invest up? The environmental effects of foreign direct investment from less-developed countries. World Dev 40(11):2221–2233

Zhang YJ (2011) The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39(4):2197–2203

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