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RESEARCH ARTICLE

Exploring the dynamic relationship between financial development, renewable energy, and carbon emissions: A new evidence from belt and road countries

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Abstract

This empirical study examines the endogenous relationship between carbon emissions (CO_2), financial development, renewable energy, globalization, and institutional quality in 64 belt and road initiative countries (BRI) using a two-step system generalized method of moments (GMM) approach with panel data over the period 2003 to 2018. Furthermore, this study used (Dumitrescu & Hurlin, 2012) causality test to estimate the variables' causal relationship. The results indicate that financial development significantly increases CO_2 emissions and causes environmental degradation in BRI countries. However, renewable energy and globalization mitigate CO_2 emissions and improve the quality of the environment. Institutional quality was positive in correlation with CO_2 emission and indicates bad governance, corruption, weak bureaucracy, and improper implementation of environmental laws cause environmental degradation. Further, the study also reports a bidirectional relationship of financial development, renewable energy, and institutional quality with CO_2 emissions and a unidirectional causality running from globalization to CO_2 emissions in BRI countries. This study offers policymakers insight into restructuring the financial system, energy consumption pattern, and global integration and improving institutions' quality for a sustainable environment and the economy at the national and regional levels.

Keywords Financial development · Carbon emissions · Renewable energy · Globalization · Institutional quality

Introduction

Global warming and climate change are the most severe global threats the world is facing today. Globalization and economic growth are the essential factors that raise carbon emissions (CO_2) and greenhouse gases (GHGs). For the past few decades, global warming and climate change have been subjects of discussion and concern among research scholars, experts, and governments. Carbon emissions (CO_2) contribute 60% of greenhouse gases, which are the cause of global warming and climate change (Eren et al., 2019; Ozturk & Acaravci, 2010; Wang & Chen, 2014). Moreover, extracting natural resources (e.g., natural oil, gas, and coal) without any compensation directly impact environmental quality. According to an estimate, in the past 130 years, there has been approximately a 45% increase in carbon emission (Carbon Footprint, 2018, Adger & Coauthors, 2018).

Thus, scholars, governments, and experts have agreed that the Paris global climate conference objectives (COP21) can only be attained by minimizing the carbon and greenhouse gas emissions (Bhattacharya et al., 2017; Pérez et al., 2017). However, Cardenas et al. (2016) believe that global efforts

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against global warming and climate change are insufficient. Hence, it is crucial to have pro-environmental regulations and policies. However, scholars, experts, and economists' biggest challenge is to make a combined plan (by formulating new policies and environmental laws by keeping the same pace of economic growth) against environmental degradation (Charfeddine et al., 2018; Kahia et al., 2017).

In practical terms, while making an environmental strategy that can reduce carbon emissions, it is essential to consider several policy options. Mainly, from the macro-economic, ecological, energy, governance, and global perspectives, the following propositions are of particular interest: (1) development of the financial sector (FD), (2) switching toward renewable energy (REC), (3) promoting globalization (GB), (4) improving institutional quality (IQ), and (5) interaction between financial development and renewable energy, globalization, institutional quality, GDP, and carbon emissions.

The first proposition entails financial development, which is a source of financing for various projects and interconnects with economic growth (GDP) and environmental quality (Khan et al., 2017). The financial sector lends to private creditors through institutions, and economic activities occur (Khan, 2001). However, it is still questionable whether financial development improves the quality of the environment (Khan et al. (2017), Saud et al. (2020), Wang et al. (2020), and Zhang (2011)). Some researchers (Saud et al., 2018; Shahbaz et al., 2013, 2018) argue that financial development improves the environment's quality.

The second proposition is based on promoting renewable energy consumption (REC) as it helps cut down carbon emissions. Chang et al. (2020) state that fossil fuel energy is the primary source of carbon emission and environmental degradation. IEA and OEC (2018) state that renewable energy consumption will increase by 60% by 2040. Sadorsky (2011) claims that it is important to have 50 to 80% of the energy being used as renewable for a clean and green environment. Recent studies (Balsalobre et al., 2018; Z. Khan et al., 2020) have argued that the global industrial structure is switching toward sustainable and green economics, reducing carbon emissions. Bao and Xu (2019), Charfeddine and Kahia (2019), Hao et al. (2021), Rahman and Velayutham (2020), and Uzar (2020) indicate that switching to renewable energy would lead to a sustainable environment.

Globalization is another important factor in the social, economic, and political aspects of life. It connects economies through financial development and foreign direct investment GDP and causes environmental degradation in carbon and sulfur emissions (Mishkin, 2009; Shahbaz et al., 2015). Globalization accelerates financial activities by increasing the demand for goods and services (Gökmenoğlu & Taspinar, 2016). Consequently, economic activities increase energy consumption, leading to environmental degradation (Ozatac et al., 2017). Previous studies have mixed findings regarding globalization and its impact on the environment. One school of thought argues that globalization improves the quality of the environment (Jorgenson & Givens, 2014; Li et al., 2015; Shahbaz et al., 2016, 2017, 2019; Zafar et al., 2019; Zaidi et al., 2019). Conversely, another school of thought (Doytch & Uctum, 2016; Saud et al., 2020; Shahbaz et al., 2015) indicates that globalization causes carbon emissions.

Another critical proposition is institutional quality, which entails corruption, good governance, the implication of law, and the quality of bureaucracy. It is an ignored factor in the context of environmental quality and climate change (Godil et al., 2020; Hunjra et al., 2020; Ibrahim & Law, 2016; Z. Wang et al., 2018). Institutional quality is vital to adopting renewable energy, green investment, and global trade through various factors, mainly focusing on the cost of adaptation and willingness to pay or policy choice (Cole, 2007; Dutt, 2009; Tamazian & Bhaskara, 2010). Institutional quality improves environmental quality when government institutions effectively implement environmental laws and regulations (Lau et al., 2014). Unlike previous studies, we focus on how explanatory variables and carbon emissions depend on belt and road initiative countries (BRI) institutional differences. Does this difference among the BRI countries have implications for green investment, renewable energy, and globalization? Finally, does institutional quality help in reducing carbon emissions in BRI countries?

This research study focuses on BRI, a group of new emerging countries. This "silk and road economic belt" comprises more than 65 countries (48 more countries showed interest), launched in December 2014 with a starting investment of 1.4 trillion to 6 trillion US dollars. BRI countries consist of 4.4 billion people covering 62.3% of the world population and represent 34% of world GDP (NDRC, FM, and MC, 2015). BRI co-operation countries cover the western Pacific's beltline to the Baltic Sea, with enormous economic significance. This project focuses on facilitating free trade for BRI countries by giving physical and digital access to global markets through global integration (globalization), financial integration, infrastructure, trade openness, and efficient use of resources, with policymaking and coordination within the region (Institutional quality) (Chin, 2017; Chin et al., 2015). All these factors create additional demand for energy, which directly impacts the environment. Hence, this project's core objectives are to provide healthier financial and global integration, switching toward green energy, and better governance to improve the quality of the environment (HKTDC, 2017).

For theoretical propositions, global warming and environmental quality have become a core issue for the future of BRI economies. Therefore, it is essential to address core factors like how financial development, energy consumption, globalization, and institutional quality influence carbon footprint. This study's implication will unfold the vision and objectives useful for policymakers and relevant authorities. Further, it will advise stakeholders regarding the policy necessary to cut down carbon emissions through expected financial development, energy consumption, and globalization.

Considering the above arguments related to environmental adversity, this study conducts an in-depth investigation particularly in the aspects of the economy, energy, regional connectivity, governance, and ecology as follows: first, this empirical research fills the gap in the literature by incorporating financial development (FD), renewable energy (REC), globalization (GB), and institutional quality (IQ) as primary explanatory variables for environmental quality (CO_2) in a single multivariate framework. Besides, we also used GDP and socioeconomic factors as control variables. As per our best knowledge, this will be the first study incorporating institutional quality as an explanatory variable with financial development, renewable energy, and globalization concerning carbon emissions in the same framework. Second, previous studies have had mixed results regarding explanatory variables on environmental quality (CO_2). To address these issues, we will provide a comprehensive guideline for policymakers, institutions, and other stakeholders to formulate new policies, techniques, and laws to cut down on carbon emissions. Third, we used a dynamic system, "Generalized Method of Moment" (GMM), a panel technique for reliable findings. Unlike other econometric techniques, it addresses heterogeneity and endogeneity by using Hansen/Sargan test and providing additional information about autocorrelation AR (1) and AR (2). Further, we also used panel Granger causality to check the causal relationship between the variables. Fourth, our study sample comprises 64 BRI countries with a selection of 16 years starting from 2003 to 2018.

The road map of the paper is as follows: the second section provides a literature review of past studies, the third presents data sources, the fourth presents empirical results, and the fifth provides discussion and conclusion.

Literature review

This article is based on past literature, which indicates the nexus of financial development, renewable energy, globalization, institution quality, and carbon emissions.

Financial development and carbon emissions

Since the EKC concept was proposed by Grossman and Krueger (1995), several studies have examined the nexus between FD and CO_2 emission. Financial institutions provide funds to investors and the household sector so economic activities take place but also cause environmental degradation (Khan, 2001). However, there is no consensus among researchers. Khan et al. (2017) investigated the nexus between financial development, energy consumption, trade, urbanization, and carbon emissions in the case of 34 upper middle-income countries of the world. Using panel vector error correction (PVAR) and fully modified ordinary least square (FMOLS) model, results confirm that financial development causes environmental degradation in European and Asian countries. Similarly, Saud et al. (2020) analyzed the impact of financial development and globalization on the ecological footprint (environment) in BRI countries. The study used a panel ARDL model with a sample period from 1990 to 2014. Results indicate that financial development and globalization cause environmental degradation. The relationship between financial development and carbon emissions was also studied (Charfeddine & Kahia, 2019; Wang et al., 2020; Zhang, 2011; Zioło et al., 2020) and it was supported that financial development causes carbon emissions.

Shahbaz et al. (2013) studied the relationship of Indonesia's financial development, energy consumption, trade openness, and carbon emissions. Using the ARDL and VECM Granger causality test, findings confirm that financial development and trade openness improve the environment's quality; however, GDP and energy consumption increased carbon emissions. Saud et al. (2018) and Shahbaz et al. (2018) also investigated the relationship between financial development and carbon emissions. Their findings indicate that financial development improves the quality of the environment by mitigating carbon emissions.

Renewable energy consumption and carbon emission

One of the critical factors for a green and clean environment is switching to renewable energy. Several previous studies have examined the relationship between renewable energy and its impact on environmental quality. To extend the argument, Bhattacharya et al. (2017) analyzed the association between renewable energy and institutional quality for carbon emissions in 84 countries of the world. They used the GMM and FMOLS model; results indicate that renewable energy and carbon emissions improve the environment's quality by reducing carbon emissions.

Similarly, Balsalobre et al. (2018) conducted a study in five European countries to investigate the impact of renewable energy, trade openness, GDP, and natural resources on carbon emissions. Results indicate that renewable natural resources improve environmental quality; however, GDP and trade openness cause carbon emissions. Hao et al. (2021) and Khan et al. (2020) investigated the relationship of renewable sources with environmental quality in G7 countries. They showed that green energy improves the quality of the environment. Moreover, Bao and Xu (2019), Charfeddine and Kahia (2019), Rahman and Velayutham (2020), and Uzar (2020) also reported the same trend for renewable energy and carbon emissions.

Table 1 Summary of the literature review

Study	Sample size/region	Modeling technique(s)	Main findings
Charfeddine and Kahia (2019)	Middle East and North Africa (1980–2015)	PVAR	FD is positive but insignificant, but REC improves environmental quality. However, GDP causes carbon emissions
Khan et al. (2017)	34 countries of the world (2001–2014)	PVAR/FMOLS	FD, FDI, and urbanization cause carbon emissions; however, REC improves the environment's quality
Saud et al. (2020)	BRI countries (1990–2014)	PARDL and Granger causality	FD and GB cause carbon emissions and have a feedback relationship with carbon emissions
Wang et al. (2020)	N-11 countries (1990–2017)	Common correlated effect mean group and augmented mean group	FD and GDP increase carbon pollution; however, REC and human and energy innovation improve the environment's quality
Zhang (2011)	China (1986–2009)	VAR/Granger causality	FD and GDP stigmatically cause environmental degradation
Zioło et al. (2020)	European countries (2008–2017)	Eigen analysis	FD causes environmental degradation
Shahbaz et al. (2013)	Indonesia (1975–2011)	ARDL/VECM Granger causality	FD and trade openness improve the quality of the environment, but GDP and energy consumption cause carbon emissions
Shahbaz et al. (2018)	France (1955–2016)	Bootstrapping ARDL	FD improves the quality of the environment but foreign direct investment and energy cause carbon emissions
Saud et al. (2018)	BRI (1980–2016)	Dumitrescu and Hurlin model (DSUR)	FD and foreign direct investment enhance the quality of the environment
Bhattacharya et al. (2017)	85 countries (1991–2012)	System GMM/FMOLS	REC and IQ improve the quality of the environment
Balsalobre et al. (2018)	5 European countries (1985–2016)	PLS	REC and natural resource improve environmental quality, but GDP and trade openness cause carbon emissions
Khan et al. (2020)	G7 countries (1990–2017)	CCEMG/AMG	REC and technology innovation improves the quality of the environment, but GDP and imports cause carbon emissions
Hao et al. (2021)	G7 countries (1991–2017)	CSARDL	REC, human capital, and taxes improve the quality of the environment, but GDP causes carbon emissions
Zaidi et al. (2019)	APEC countries (1990–2016)	CUP-BC/CUP-FM	GB and FD improve the quality of the environment
Shahbaz et al. (2017)	China (1970–2012)	ARDL/VECM Granger causality	GB improve the quality of the environment
Shahbaz et al. (2019)	87 countries (1970–2012)	Cross-correlation approach	GB cuts down the carbon emissions
Shahbaz et al. (2016)	African countries (1971–2012)	PARDL	GB improves the quality of the environment
Shahbaz et al. (2015)	India (1970–2012)	PARDL	GB, FD, GDP, and energy consumption increase environmental degradation
Ibrahim and Law (2016)	40 African countries (2000–2010)	Dynamic GMM	IQ improves the quality of the environment but trade impacts the carbon emissions demand of IQ
Z. Wang et al. (2018)	BRICS countries (1996–2015)	Piratical least square regression	Corruption weakens the relationship between carbon emissions and GDP
Godil et al. (2020)	Pakistan (1995–2018)	Quantile ARDL	IQ and GDP cause carbon emissions, but FD and information technology improves the quality of the environment
Hunjra et al. (2020)	5 south Asian countries (1984–2018)	GLS	IQ negatively moderates FD and carbon emissions

Globalization and carbon emissions

Another vital variable that directly impacts the quality of the environment is globalization. Though past studies provide mixed evidence related to globalization and its effects on environmental quality. To extend the argument, a school of thought claims that globalization improves the quality of the environment. Sheraz et al. (2021) revealed that globalization helps developing countries import new technology for efficient energy use. Zaidi et al. (2019) investigated the linkage of globalization and financial development with carbon emissions in Asia-Pacific economic co-operation countries. Using the data from 1990 to 2016, results demonstrate that globalization and financial development cut down carbon emissions. Furthermore, Jorgenson and Givens (2014) and Zafar et al. (2019) also reported that globalization improves the environment's quality. Shahbaz et al. (2017) used the ARDL test to confirm that globalization enhances the quality of the environment. Shahbaz et al. (2016, 2019) investigated 87 high-, middle-, and low-income countries and selected African countries. Their findings confirm that globalization improves the quality of the environment.

Conversely, another school of thought supports the argument that globalization causes carbon emissions. Shahbaz et al. (2015) conducted a study in India to investigate the linkage of globalization, financial development, GDP, and energy consumption with carbon emissions. Results of the study showed that globalization, financial development GDP, and energy consumption increased carbon emission. Similarly, Saud et al. (2020) investigated the impact of globalization, financial development, GDP, and energy consumption on carbon emissions in BRI countries. Findings also confirm that globalization causes environmental degradation. Doytch and Uctum's (2016) findings also indicate that globalization increases carbon emissions.

Institutional quality and carbon emissions

Institutional quality is the most ignored factor in the context of environmental quality. Institutional quality plays a significant role in reducing carbon emissions. Bhattacharya et al. (2017) analyzed 85 countries and reported that institutional quality negatively correlates with carbon emissions and GDP. It indicates better governance and the implication of law and policies improved the environmental quality and increased the GDP. Similarly, Ibrahim and Law (2016) and Wang et al. (2018) also confirmed that better institutional quality positively moderates the GDP development and carbon emissions. Further, institutional reference improves the environment's quality but countries with low institutional quality led to environmental degradation. Table 1 presents the summary of the factors that cause carbon emissions.

Conversely, the findings of Godil et al. (2020) indicate that institutional quality and GDP increase carbon emissions but financial development, information, and communication technology reduce carbon emissions in Pakistan's case. Similarly, Hunjra et al. (2020) analyzed the nexus of financial development and carbon emissions with a moderating role of institutional quality in five south Asian countries. Results showed that institutional quality negatively moderates financial development and carbon emissions.

Model description, data, and estimations

Data collection and theoretical modeling

This study examined the effects of financial development, renewable energy, globalization, and institutional quality on carbon emission for 64 belt and road initiative countries (BRI) for 2003 to 2018 as per data availability. Our study sample comprises upper middle-, middle-, or lower-income countries of East Asia, South Asia, Central Asia, Middle East, North Africa, South Africa, and Europe (details in Appendix 1 Table 9). The study sample is based on secondary data obtained from world development indicators (WDI) and the international country risk guide (ICRG) database (Appendix 2, Table 10).

The variables selected for the analysis are as follows: (1) carbon emissions are measured in per capita metric tons; (2) financial development index comprises sub-indices of financial market index and financial institutional index; (3) renewable energy is the aggregate of wind, hydro, solar, geothermal, marine, waste, and gaseous biofuel derived energy; (4) KOF proposes the globalization index and comprises sub-indices of economic, social, and political global indices; (5) the institutional quantity index comprises six governance indicators (the rule of law, control of corruption, government effectiveness, voice and accountability, regulatory quality, and political stability and absence of terrorism); (6) GDP is the measure of growth which is constant 2010 US dollars; (7) socioeconomic index comprises sub-indices of poverty index, consumer price index, and unemployment. All the determents are transformed into natural logarithm form (except financial development index globalization index, and intuitional quality index).

The study's empirical framework is based on carbon emissions (CO_2) as a dependent variable, while financial development, renewable energy, globalization, and institutional quality are explanatory variables. We also used gross domestic product (GDP) and socioeconomic factors (SEC) as control variables. The framework or functional form of our model is specified as follows:

$$CO2 = \int(FD, \ REC, GB, IQ, GDP, SEC) \qquad (A.1)$$

where FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions.

Based on previous literature, FD is the primary source of funding for economic activities. Financial institutions lend to the private firms and household sectors at a low cost of borrowing. However, economic activities increase the energy demand which causes carbon emissions too. Like Khan et al. (2017), Saud et al. (2020), Wang et al. (2020), and Zhang (2011), we also expect a positive relation between FD and carbon emission. Several past studies (Bao & Xu, 2019; Charfeddine & Kahia, 2019; Rahman & Velayutham, 2020; Uzar, 2020) have argued that RE improves the environmental quality by decreasing the carbon emissions so we also assume a negative impact of RE on carbon emission. Another important determinant is GB which has a significant effect on environmental quality. GB helps invest in green projects and import green technology from developed countries that mitigate the energy impact on the environment. Based on some studies' findings (Zaidi et al., 2019, Jorgenson & Givens, 2014; Zafar et al., 2019, Shahbaz et al., 2016, 2019), we expect a negative impact of GB on carbon emissions in BRI countries. Finally, IQ, which comprises six sub-indices, is vital in improving environmental quality as strong institution and better governance help implement the environment-related laws and regulations. Based on the previous findings (Godil et al., 2020; Hunjra et al., 2020; Ibrahim & Law, 2016; Wang et al., 2018), we expect a negative impact of IQ on carbon emissions in BRI countries.

Empirical estimation techniques

Diagnostics tests (IPS and CIPS unit root, CD test)

This study employed the most advanced econometric approach to test cross-sectional dependence (CD) between the variables as conventional econometric techniques cannot address this issue. Therefore, we adopted Pesaran's (2004)cross-sectional dependence test which is crucial before a unit root test. We used the following equations for cross-sectional dependence and Lagrange multiplier (LM):

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=0}^{N-1}\sum_{j=i+1}^{N}\rho ij\right)} \tag{A.2}$$

$$y_{it} = \alpha_{it} + \beta_i x_{it} + \mu_{it} \tag{A.3}$$

Further, to confirm the stationarity of the variables, we employed second-generation IPS (i.e., CADF) and CIPS (i.e., CIPS) unit root test proposed by Pesaran (2007). The unit root test helps confirm the integration order, whether the variable is stationary at level i(0) or first difference i(1). The following equations are used to estimate CADF and CIPS unit root test:

$$y_{it} = \alpha_{it} + \beta_i x_{it-1}\rho_i T + \sum_{j=0}^{n} {}_{it}\triangle x_{i,t-j} + \mu_{it} \tag{A.4}$$

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADFi \tag{A.5}$$

Pairwise Dumitrescu and Hurlin causality test

After confirmation of CD, this study employed the causality test proposed by Dumitrescu and Hurlin (2012) based on the individual Wald statistic of Granger (1969) test. The empirical representation of the test is as follows:

$$y_{it} = \alpha_i + \sum_{j-1}^{J} \lambda_j^i y_{i(t-j)} + \sum_{j-1}^{J} \beta_j^i X_{i(t-j)} + \mu_{it} \tag{A.6}$$

where y and x indicate the numbers of observations and λ and β_{ji} are the coefficients of regression and autoregressive parameters. The null hypothesis demonstrates no causal association among the variables and shows a causal relationship between the variables.

Two-step system GMM

This study's primary objective is to examine the impact of exoplanetary variables (i.e., FD, REC, GB, and IQ on CO_2 for BRI countries). However, due to the panel nature data, this study employed panel estimation techniques. The traditional panel models (pooled OLS, random, and fixed-effect panel) are unsuitable due to country-specific effects, endogeneity of independent variables, and lagged dependent variables. Besides, error terms are not auto-correlated; therefore, traditional techniques do not efficiently estimate the results (Beggs & Nerlove, 1988). Arellano and Bond (1991) proposed a panel estimation technique known as the generalized method of moments (GMM) to address the issues mentioned above. In contrast with other panel estimation techniques, GMM addresses the issues of endogeneity, error of measurement, omitted variables, and autocorrelation issues. For instance, by taking the first difference, it can solve country-specific effects or time-invariant variable.

Moreover, to address the issues of correlation between lagged dependent variables and disturbance terms after the first difference, Arellano and Bond (1991) used instrumental variables (differenced lagged depended on variables and endogenous variables instrumented with their lags at levels; however, lagged two or more exogenous variables can serve their own instruments). GMM is further categorized into system GMM and difference GMM based on different weight matrixes. Each of them can be further divided into one- and two-step GMM. However, system GMM is a better estimator technique than difference GMM, and two-step GMM better addresses the issues of heteroscedasticity and autocorrection than one-step GMM (Arellano & Bover, 1995; Blundell & Bond, 1998; Arellano & Bond, 1991).

One of the primary criteria for system GMM is that the number of cross-sections (*N*) should be greater than period (*T*), which was met by the sample of this study, where *T*=16 and *N*=64 (N>T). Therefore, to achieve this study's objectives, we adopted a dynamic panel model (two-step system GMM) for the estimation. Unlike the static panel estimation technique, the dynamic panel model added lag term of the explained variable as the dependent variable. This will show the dynamic process of CO_2 emissions close to reality. Besides, adding a lag term improves the regression outcomes' authenticity by addressing the impact of uncontrollable determinants.

Like past studies conducted by Adeleye and Eboagu (2019), Arminen (2018), Arminen and Menegaki (2019),

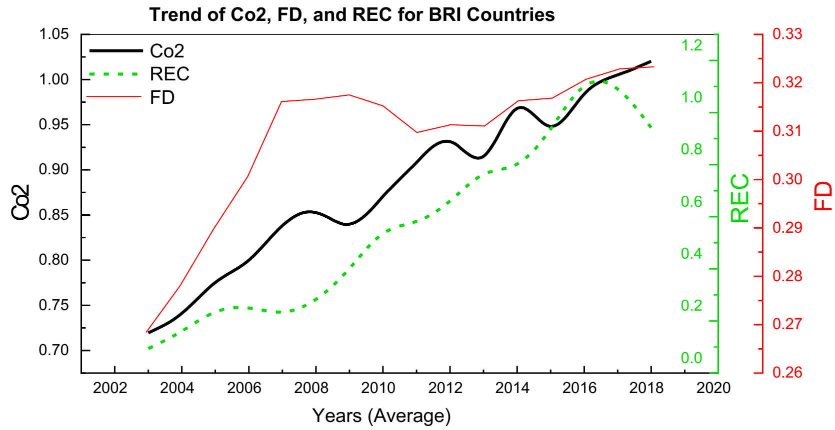

Fig. 1 CO_2, REC, and FD represents carbon emissions, renewable energy consumption, and financial development. Source: Authors Estimations Origin-Pro 2018

and Ullah et al. (2021), the structural equations of simultaneous equations model can be as follows:

$$Y_{\text{it}} = X_{\text{it}}\beta + \delta y_{i,t-1} + c_i + \varepsilon_{it} \tag{A.7}$$

$$\Delta\gamma_{it} = (\Delta X_{it})\beta + \delta\left(\Delta y_{i,t-1}\right) + \Delta\varepsilon_{it} \tag{A.8}$$

where the subscripts "*t*" and "*i*" indicate time and countries, such as *t*= 1,. . , *T* (16 years), *i* = 1, . . . , *N* (64 countries). Further, it is considered that the error term is the combination of idiosyncratic shocks ε_{it} and fixed individual effects c_{i} with the following characteristics: E [c_{i}] = E[ε_{it}] = [$c_{\text{i}}\varepsilon_{\text{it}}$] = 0. Moreover, in Equation A.7, the individual effect $c_{\text{I is}}$ eliminated, where Δ represents the first difference.

The linear form of static and dynamic model is as follows:

$$Co2_{i,t} = \beta_0 + \beta_1(FD)_{i,t} + \beta_2(REC)_{i,t} + \beta_3(GB)_{i,t} + \beta_4(IQ)_{i,t} + \beta_5(GDP)_{i,t} + \beta_6(SEC)_{i,t} + \varphi_t + \mu_{i,t} \tag{A.9}$$

$$Co2_{i,t} = \alpha_i + \lambda(Co2)_{i,t-1} + \beta_1(FD)_{i,t} + \beta_2(REC)_{i,t} + \beta_3(GB)_{i,t} + \beta_4(IQ)_{i,t} + \beta_5(GDP)_{i,t} + \beta_6(SEC)_{i,t} + \varphi_t + \mu_{i,t} \tag{A.10}$$

where *i* and *t* denote country-specific values and time, and CO_2, FD, REC, GB, IQ GDP, and SEC represent carbon emissions, financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively. Here, to account for temporal dependence on CO_2, we used lagged dependent variable, which presents the gradual changes in technology and production structure. Further, α_i indicates country-specific effect; λ , β1, β2, β3, β4, β5, and β6 represent the coefficients of cross-ponding explanatory variables; φ_t indicates the year dummies as it controls the common shocks (like global finial crises during 2007-2009); and $\mu_{i,\ t}$ reports the error term.

Furthermore, to conduct the estimation, we used Stata-15 software and the "Xtabond2" command. Roodman (2009) in his study provided more explanation about this command. We adopted the Hansen test over the Sargan test as it is more robust concerning autocorrelation and heteroscedasticity (Roodman, 2009). Further, the Hansen test addresses the instrument's reliability and controls over-identifying restrictions. A serial correlation test is used to confirm the estimator's consistency as it is based on first- and second-order autocorrelation estimators.

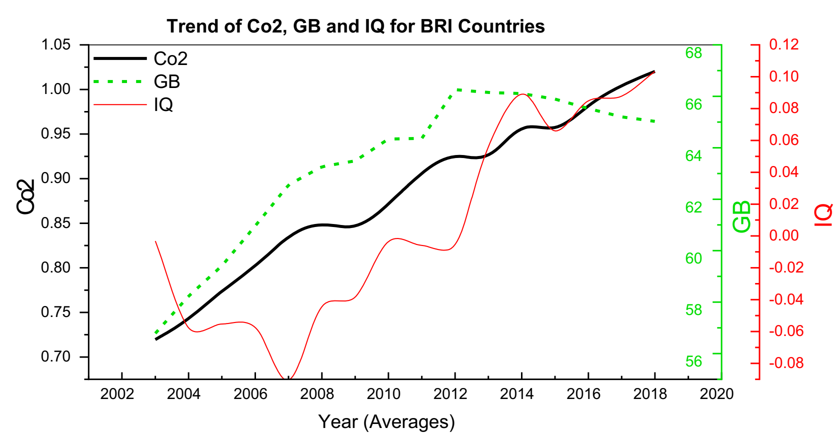

Fig. 2 CO_2, GB, and IQ represent carbon emissions, globalization, and financial institutional quality. Source: Authors Estimations Origin-Pro 2018

Table 2. Descriptive statistics

Variables	Obs	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis
CO_2	1024	1.01	1.25	1.46	3.6	–2.9	–0.66	2.1
FD	1024	0.32	0.31	0.17	0.7	0.07	0.44	2.2
REC	1024	0.60	1.18	2.71	7.50	–6.90	–0.52	2.1
GB	1024	64.5	65.2	12.5	85.1	33.4	–0.44	2.6
IQ	1024	0.07	–0.10	1.01	3.4	–1.75	0.72	2.7
GDP	1024	2.27	2.45	1.01	3.6	–3.06	–1.42	2.9
SEC	1024	5.79	5.66	1.86	11	1.5	0.33	2.7

Note: Same as below, FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively

Estimation results and discussion

Figure 1 presents the impact of FD and REC on CO_2 emissions, and suggests that the path of FD and REC influences the path of emissions of CO2 in BRI countries. Figure 1 indicates an upward trend of FD increasing carbon emissions; however, after 2016, a downward trend of REC suggests it mitigates carbon emissions.

Similarly, the trend in Fig. 2 suggests the downward movement of IQ because of CO_2 emissions from 2003 to 2007 but onward shows an upward movement. Between 2003 and 2012, globalization shows an upward movement but onward shows a downward trend which suggests the mitigation of CO_2 emissions in BRI countries.

Table 2 presents the descriptive summary of the variables which indicates that the results of all variables of the study for mean, median, standard deviation, minimum, maximum, skewness, and Kurtosis are normalized. Moreover, the normal distribution probability trend of the curves for all the determinants are reported in Appendix 3 Fig. 3.

Table 3 presents the results of pairwise correlation indicating the degree of relationship. All the independent variables have positive and significant relationships with CO_2 emissions. The basic function of the correlation matrix is to detect issues of multicollinearity. Usually, it is assumed that if the coefficient values of variables are less than 0.85, then there are no multicollinearity issues in the model (Hunjra et al., 2020; Jiang & Ma, 2019; Krammer, 2010). Results of correlations indicate no multicollinearity issue as the coefficient value of all dependent variables is less than 0.85. Besides, we employed the VIF test which confirmed that our sample of the study has no multicollinearity issues as the value of the VIF test is lower than the standard limit of 5.

Further, to confirm the existence of cross-sectional dependency, we performed the CD test, which are reported in Table 4. Results indicate that the null hypothesis of no-CD is rejected and an alternative hypothesis for the existence of CD is accepted. In the presence of CD and heterogeneity, we also employed the second-generation IPS (i.e., CADF) and CIPS unit root test to check the stationarity of the variables.

Table 3. Pairwise correlations

Variables	CO_2	FD	REC	GB	IQ	GDP	SEC	VIF
CO_2	1.000							2.145
FD	0.466***	1.000						1.091
REC	0.013	0.208***	1.000					2.142
GB	0.398***	0.624***	0.010*	1.000				1.475
IQ	0.475***	0.418***	–0.054*	0.488***	1.000			1.457
GDP	0.309***	0.292***	0.110***	–0.008	0.248***	1.000		1.271
SEC	0.550***	0.502***	0.105***	0.458***	0.360***	0.231***	1.000	1.457
Mean VIF								1.597

Note: FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively

Note: Standard errors in parentheses at 1%, 5%, and 10% levels are ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$, respectively. VIF denotes variance inflation factor

Table 4. Cross-sectional dependence test (CD test)

Tests	Breusch-Pagan LM		Pesaran scaled LM		Bias-corrected scaled LM		Pesaran CD	
Variables	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
CO_2	1345.2	0.000	179.1	0.000	177.1	0.000	26.5	0.000
FD	896.7	0.000	108.4	0.000	106.2	0.000	42.5	0.000
REC	689.5	0.000	65.7	0.000	62.4	0.000	5.6	0.000
GB	2287.1	0.000	327.4	0.000	325.2	0.000	147.8	0.000
IQ	709.2	0.000	78.9	0.000	76.8	0.000	7.1	0.000
GDP	636.6	0.000	67.5	0.000	65.4	0.000	6.3	0.000
SEC	661.3	0.000	71.4	0.000	69.2	0.000	13.1	0.000

Note: FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively

Note: Standard errors in parentheses at 1%, 5%, and 10% levels are ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$, respectively

Table 5 presents the CPIS and CADF results. Regarding CPIS test, CO_2, FM, GB, IQ, GDP, and SEC are stationary at level; however, REC is stationary at first difference. The CADF unit root test exhibits a mixed order of integration as FM, GB, and IQ stationary at level; however, CO_2, REC, GDP, and SEC are stationary at first difference.

Table 6 presents the results of the static and dynamic models of the study. However, we preferred a two-step system GMM (dynamic model) over a static model as it is consistent for output and the instrument's validity (tests for autocorrelation and over-identification). Similarly, specification tests confirm that two-step system GMM is appropriate for study as statistic results show that AR (1) = –2.110 is significant with *p* value 0.0349, $p < 0.05$, 5%, whereas AR (2) = –0.729 is insignificant with *p* value 0.466, $p > 0.05$, 5%. This indicates that the serial correlation test cannot reject the null hypothesis of no second-order autocorrelation. However, the null hypothesis of no first-order autocorrelation is rejected, confirming that second-order autocorrelation results are not affected. Similarly, the Hansen test value = 42.88 was insignificant with a *p* value 0.169, $p > 0.05$, 5%, implying that the null hypothesis fails to reject the instrumental validity and supports it. We also observed the time effect of explanatory variables on carbon emissions Appendix 4 Table 11, which suggests CO_2 emissions increased in BRI countries over the year.

Based on the two-step system GMM results (column 5), FD is statistically significant at the 1% level with optimistic influence on CO_2 emissions, suggesting that a 1% increase in FD can increase the CO_2 emissions by 0.471% in BRI countries. This finding reveals that FD facilities offer a low rate of borrowing with lesser restrictions for development projects. Consequently, the low cost of financing encourages the private and household sectors to invest in new development projects (purchasing machinery and equipment) and durable goods (car, household appliance, and other luxury items) which accelerates the energy demand and adversely affects the impact on environmental quality. Besides, most countries

Table 5. Pesaran CIPS unit root test and cross-sectional dependence test

CPIS				CADF		
Variables	Level	1st difference	Order	Level	1st difference	Order
CO_2	–2.559*	-	I(0)	–2.037	–2.868***	I(1)
FM	–3.248***	-	I(0)	–2.713**	-	I(0)
REC	–2.559	–2.949 ***	I(1)	–2.369	–2.349***	I(1)
GB	–3.055***	-	I(0)	–2.078 *	-	I(0)
IQ	–2.309***	-	I(0)	–2.168**	-	I(0)
GDP	–2.260***	-	I(0)	–1.921	–2.635***	I(1)
SEC	–2.155**	-	I(0)	-	–2.387***	I(1)

Note: FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively

Note: Standard errors in parentheses at 1%, 5%, and 10% levels are ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$, respectively under the BRI platform have low- or middle-income economies (developing countries). Therefore, unlike developed countries, they attempt to boost their economic growth while compromising environmental quality (not focused on green finance or change in technology) (Charfeddine & Kahia, 2019; Wang et al., 2020; Zhang, 2011; Zioło et al., 2020).

Moreover, REC reports the estimated value of the coefficient as statistically significant and negatively correlated with CO_2 emissions, indicating that a 1% change in REC can decrease CO_2 emissions by –0.001% with a significance level of 5% in BRI countries. This finding is laudable and demonstrates that countries switching to REC can help improve the environment's quality by mitigating CO_2 emissions. The world is shifting toward clean and green energy sources, so it is crucial to employ advanced technology and environmentally friendly sources of energy generation to create a sustainable environment. This result advocates the recent studies (Bao & Xu, 2019; Charfeddine & Kahia, 2019; Hao et al., 2021; Rahman & Velayutham, 2020; Uzar, 2020) identifying the significance of REC for a sustainable environment.

Similarly, GB, which is an essential determinant for climate change, indicates a significant and positive influence on the environment (CO_2) as 1% change in GB can reduce CO_2 emissions by –0.003% with a significance level of 10% in BRI countries. It suggests that in BRI countries, GB connects countries which mitigate obstacles to making

Table 6. Estimated results of two system-GMM

Dependent variable	(1) Static model	(2)	(3) Dynamic model	(4)	(5)
	Panel pooled OLS CO_2	Panel fixed effect CO_2	Pooled OLS CO_2	Panel fixed effect CO_2	Final model of two-step system GMM CO_2
L. CO_2			0.991***	0.809***	0.471***
			(0.003)	(0.020)	(0.021)
Financial development	5.818***	2.223	0.072	0.383	4.310***
	(1.502)	(1.685)	(0.132)	(0.479)	(0.872)
Renewable energy	–0.003**	0.002***	0.000	0.000	–0.001**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Globalization index	0.025	–0.008	–0.003**	–0.006	–0.003*
	(0.021)	(0.031)	(0.002)	(0.009)	(0.009)
Institutional quality (WDI-PCA)	1.708***	0.768	0.043**	0.195***	0.775***
	(0.213)	(0.518)	(0.019)	(0.072)	(0.087)
Gross domestic products (GDP)	0.083***	0.001	–0.001	0.002	0.030***
	(0.017)	(0.014)	(0.001)	(0.003)	(0.004)
Socioeconomic conditions	1.396***	0.006	0.020*	0.077***	0.592***
	(0.114)	(0.111)	(0.011)	(0.028)	(0.052)
Constant	Yes	Yes	Yes	Yes	Yes
Observations	1,024	1,024	960	960	960
R-squared	0.429	0.131	0.996	0.697	
AR1	.	.	.	.	–2.110
AR1 (p value)	.	.	.	.	0.0349
AR2	.	.	.	.	–0.729
AR2 (p value)	.	.	.	.	0.466
Hansen	.	.	.	.	42.88
Hansen (p value)	.	.	.	.	0.169
Wald/CHI2 test	.	.	.	.	123943
Wald/CHI2 test (p value)	.	.	.	.	0

Note: FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions

Note: Standard errors in parentheses at 1%, 5%, and 10% levels are ***p < 0.01, **p < 0.05, and *p < 0.1, respectively. Number of instruments are 59, while number of groups are 64 (instrument < groups). Moreover, used year effect as suggested by Roodman (2009) standards Stata Xtabond2 command investments and trade. As a result, new technology can be imported, and green investment opportunities are created, improving the quality of the environment by reducing CO_2 emissions. Moreover, an increase in competition among GB firms encourages innovation and focuses on the latest techniques to improve the quality of products and services and address climate change issues. Our findings are consistent with previous studies (Jorgenson & Givens, 2014; Li et al., 2015; Shahbaz et al., 2016, 2017, 2019; Zafar et al., 2019; Zaidi et al., 2019).

Moreover, in the case of IQ, we have interesting findings for BRI countries. Results indicate that IQ is statistically significant and positively correlated with CO_2 emissions, which suggests that in BRI countries, bad governance, weak bureaucracy, corruption, and improper implication of climate laws lead to an increase in carbon emissions. Policymakers and concerned authorities must focus on institutional quality because better governance and implementation of law and policies improve environmental quality (Bhattacharya et al.,

Table 7. Results robustness check with alternate variables

Dependent variable	(1) Static model	(2)	(3) Dynamic model	(4)	(5)
	Panel pooled OLS CO_2	Panel fixed effect CO_2	Pooled OLS CO_2	Panel fixed effect CO_2	Robust final model of two-step system GMM CO_2
L. CO_2			0.990***	0.782***	0.466***
			(0.003)	(0.021)	(0.023)
Financial markets development (robust)	9.167***	0.646	0.115	0.104	1.166**
	(0.988)	(1.027)	(0.097)	(0.319)	(0.534)
Financial institutions development (robust)	–11.680***	0.973	–0.209	–0.054	4.273**
	(1.500)	(1.113)	(0.145)	(0.432)	(1.850)
Renewable energy	–0.003**	0.001***	0.000	0.000	–0.001**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Economic globalization index (robust)	0.019	–0.030**	–0.003	–0.007	–0.027***
	(0.020)	(0.015)	(0.002)	(0.005)	(0.010)
Institutional quality (ICRG-PCA)	1.637***	0.540	0.051**	0.148**	0.604***
	(0.206)	(0.402)	(0.020)	(0.068)	(0.095)
GDP	0.059***	–0.005	–0.001	0.000	0.033***
	(0.016)	(0.013)	(0.002)	(0.003)	(0.003)
Socioeconomic conditions	0.774***	–0.010	0.018	0.076***	0.405***
	(0.122)	(0.097)	(0.012)	(0.028)	(0.067)
Human development index (robust)	18.284***	22.436***	0.321	6.063***	8.742***
	(2.132)	(6.025)	(0.211)	(1.545)	(2.277)
Constant	Yes	Yes	Yes	Yes	Yes
Observations	1,024	1,024	960	960	960
R-squared	0.507	0.229	0.996	0.702	
AR1	.	.	.	.	–2.068
AR1 (p value)	.	.	.	.	0.0386
AR2	.	.	.	.	–0.854
AR2 (p value)	.	.	.	.	0.393
Hansen	.	.	.	.	37.65
Hansen (p value)	.	.	.	.	0.226
Wald/CHI2 test	.	.	.	.	47250
Wald/CHI2 test (p value)	.	.	.	.	0

Note: Financial development robust with sub-index financial markets and institution development. IQ (ICRG-robust) represents the international country risk guide six alternate indicators of institutional quality. Globalization index robust with sub-index economic globalization. Human development index was additionally added for robustness check

Note: Standard errors in parentheses at 1%, 5%, and 10% levels are ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$, respectively. Number of instruments are 58, while number of groups are 64 (instrument < groups). Moreover, used year effect as suggested by Roodman (2009) standards Stata Xtabond2 command

Table 8. Results of Dumitrescu and Hurlin panel causality test

Null hypothesis	W-Stat.	Zbar-Stat.	p value
FD→ CO_2	5.213***	6.127	0.000
CO_2 →FD	4.127***	3.608	0.000
REC→ CO_2	4.391***	4.220	0.000
CO_2→ REC	4.482***	4.432	0.000
GB → CO_2	4.307***	4.026	0.000
CO_2→ GB	2.841	0.626	0.531
IQ→ CO_2	4.031***	3.386	0.000
CO_2→ IQ	4.517***	4.512	0.000
GDP→ CO_2	3.504**	2.162	0.030
CO_2→ GDP	2.685	0.264	0.791
SEC→ CO_2	4.190***	3.754	0.000
CO_2→ SEC	3.881***	3.038	0.002

Note: FD, REC, GB, IQ, GDP, and SEC represent financial development, renewable energy consumption, globalization, institutional quality, gross domestic product, and socioeconomic conditions, respectively

Note: Standard errors in parentheses at 1% and 5% levels are ***$p < 0.01$ and **$p < 0.05$, respectively

2017). The results of our study contradict those of past studies (Hunjra et al., 2020; Ibrahim & Law, 2016; Wang et al., 2018), however, are in line with Godil et al. (2020) which reported that IQ quality had a negative influence on the environment in the case of Pakistan.

Finally, we also reported the findings of our control variables of studies that included GDP and SEC. The reported results in Table 6 indicate that GDP hurts carbon emissions as a 1% change in GDP leads to a 0.03% reduction in emissions in BRI countries. This suggests that due to an increase in economic activities, the demand for energy increases, which also causes carbon emissions. Our findings are in line with previous studies (Charfeddine & Kahia, 2019; Shahbaz et al., 2013; Wang et al., 2020). Similarly, SEC is significant and positive in correlation with carbon emissions, suggesting that SEC also causes environmental degradation in BRI countries.

Moreover, we conducted a robustness check using alternative proxies and a new variable to check the results' reliability. For instance, we adopted sub-indexes of FD which are the financial market and financial institutions index. Similarly, we used the sub-index economic globalization as an alternative proxy for GB and for IQ, and we used the ICRG as an alternative proxy for the robust check. Furthermore, we also introduced the human development index as a new variable for the robustness check.

For robustness check, we also employed a two-step system GMM to estimate the model as it effectively addresses endogeneity issues in the dynamic panel. The estimation results of the robust check are presented in Table 7, which indicates that all the explanatory variables of the study are consistent with the previous results. Alternative proxies for FD which are financial institutions and financial market are significantly positive in correlation with CO_2. Similarly, like previous findings, REC and GB (alternative proxy economic globalization) are negatively correlated with CO_2 emission. Moreover, IQ (ICRG-robust), GDP, and SEC have a positive relationship with carbon emissions. Moreover, after including human development as a robust variable, overall findings are in line with the previous results.

Table 8 presents the results of Dumitrescu and Hurlin (2012)non-causality test which was performed to explore the nexus of CO_2 emissions with FD, REC,GB, IQ, GDP, and SEC. Results reveal a bidirectional or feedback causality relationship between FD and CO_2 which is in line with previous findings (Zaidi et al., 2019). Similarly, in REC and CO_2, we also identified a bidirectional relationship running from REC to CO_2 and CO_2 to REC. However, CO_2 is Granger caused by GB and GDP which show a unidirectional causality relationship and are consistent with Zaidi et al. (2019). There is a bidirectional causality relationship between IQ and CO_2 and SEC and CO_2 for BIR countries.

Discussion of results

The empirical results of this study can help scholars, policymakers, and governments of BRI countries. A comparative analysis between current and previous studies could help researchers and scholars to understand the role of two-step dynamic GMM modeling and (Dumitrescu & Hurlin, 2012) causality test concerning investments, consumption pattern, global integration, governance, and environmental nexus. The study also employed a CD test (Pesaran, 2004) and a second-generation unit root test (Pesaran, 2007) to determine the data's cross-sectional dependence and stationarity.

Table 6 presents the results of the dynamic and static model. However, we preferred a two-step system GMM (dynamic model) due to the instrument's consistency and validity. The findings indicate that FD hurts environmental quality which is in line with previous studies (Charfeddine & Kahia, 2019; Wang et al., 2020; Zhang, 2011; Zioło et al., 2020). Moreover, REC and GB help improve the quality of the environment in BRI countries which are consistent with previous findings (Bao & Xu, 2019; Charfeddine & Kahia, 2019; Hao et al., 2021; Rahman & Velayutham, 2020; Uzar, 2020; Jorgenson & Givens, 2014; Li et al., 2015; Shahbaz et al., 2016, 2017, 2019; Zafar et al., 2019; Zaidi et al., 2019). Further, IQ is negatively correlated with CO_2 emissions, which refers to bad governance, bureaucracy, corruption, and improper climate laws. It is in line with the findings of Godil et al. (2020). Results of the control variables GDP and SEC suggest that they deteriorate the quality of the environment. We also checked the robustness of the results by using alternative proxies and introducing new variables consistent with the main findings. Moreover, the causality relationship between the variables is presented in Table 8. A bidirectional causal relationship between FD, REC, IQ, and SEC on CO_2 emissions was obtained. However, in IQ and GDP, we reported a unidirectional causal relationship with CO_2 emissions.

Conclusion and policy implications

This study examined the impact of financial development (FD), renewable energy consumption (REC), on carbon emissions (CO_2) with a dynamic role of Globalization (GB), and institutional quality (IQ) in belt and road imitative countries (BRI). The study used panel data of 64 BRI countries covering the period 2003 to 2018. We employed CD test (Pesaran, 2004) and CADF and CIPS unit root test (Pesaran, 2007), which confirms the cross-sectional dependence and stationarity of the variables. Moreover, the two-step system GMM technique is used to estimate the relationship between explanatory variables and CO_2 emissions. The study's findings indicate that FD causes environmental degradation as financial institutions lend cheaper debts to the investors and household sector which boosts the economic activities and raises the energy demand and cause of CO_2 emissions. However, due to the import of new efficient technology and switching toward green energy, RE and GB mitigate the CO_2 emissions in BRI countries. Findings also confirm that in weak governances, bureaucracy, implementation of climate law, and corruption, the role of IQ in BRI countries is negative in correlation with CO_2 emission. This study uses Dumitrescu and Hurlin's (2012) causality test to examine the causal relationship between the variables. The findings show that FD, REC, IQ, and SEC have a bidirectional causal relationship with CO_2 emission; however, GB and GDP have a unidirectional causal relationship with CO_2 emissions.

Besides, this study also recommends the policy implication for scholars, policymakers, government officials, and other stakeholders of BRI countries, which are as follows:

- By allocating resources for socially responsible industries, investing in green government projects, and restricting anti-ecofriendly technology and projects (taxes and penalties), the financial sector can become an essential tool for sustainable development in BRI countries. Development banks must change the financial system and develop mechanisms to reduce the risk while mobilizing funds from the private sector, play a role in making policies, building capacity for green finance, and correctly identifying the level of environmental risk in various projects.
- Another crucial factor is to encourage regional connectivity through globalization. It helps attract foreign investors for financing, bringing innovative production methods, new skills and knowledge, and advanced technology. Governments should adopt international environmental laws that encourage globalization to increase renewable energy in the total energy mix for a sustainable environment and economic growth.
- Energy is vital for the economy's growth, but it is also considered the second largest source of CO_2 emissions. Therefore, introducing the renewable energy mix in the production line, importing efficient technology, R&D, and industrialization of the energy sector are vital in mitigating CO_2 emissions.
- The goal of environmental sustainability can only be achieved through good governance, eradication of corruption, transparency, quality of bureaucracy, and complete implementation of national and international environmental laws and policies in BRI countries. In other words, environmental quality depends on institutional quality.

This study has some limitations such as the sample of research based on BRI countries. This study did not account for country-specific estimation and used carbon emissions (dependent variable) per capita to proxy environment degradation. For future research, it is proposed that country-specify effects through non-linear estimation techniques and other proxies of the environment such as carbon footprint, greenhouse gases, or logical footprint might be employed.

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Data and materials availability Data are available where need on request.

Author contribution All authors contributed conceptually and formally in original drafting. All authors contributed. Responsibilities are as follows: Muhammad Sheraz: conceptualization; formal analysis; methodology; writing—original draft preparation. Xu Deyi: supervision; funding acquisition; validation; writing—review and editing. Muhammad Zubair Mumtaz: conceptualization; methodology; formal analysis. Atta Ullah: validation; writing—review and editing; conceptualization.

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Declarations

Ethics approval This study did not use any data which need approval.

Consent to participate All authors participated in the process of draft completion. All authors have read and agreed to the published version of the manuscript.

Consent to publish All authors agree to publish.

Competing interests The authors declare no competing interests.

Appendix 1

Table 9 List of BRI countries

China	Mongolia	Brunei	Cambodia	Indonesia	Laos	Malaysia
Myanmar	Philippines	Singapore	Thailand	Vietnam	Kazakhstan	Kyrgyzstan
Tajikistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Bahrain	Turkey	Israel	Jordan	Kuwait	Lebanon	Oman
Qatar	Saudi Arabia	Syria	Egypt	Algeria	Ukraine	Gambia
Burkina Faso	Mali	Senegal	Djibouti	Ethiopia	Mauritius	Rwanda
Kenya	South Africa	Albania	Armenia	Azerbaijan	Belarus	Bulgaria
Croatia	Slovenia	Estonia	Georgia	Hungary	Latvia	Lithuania
Macedonia	Moldova	Poland	Romania	Russia	Serbia	Slovakia
Czech Republic						

Appendix 2

Table 10 Data description and sources

Variables	Description	Symbols	Data sources
Carbon emissions	Carbon emissions per metric ton	CO_2	World bank (2019) WDI
Financial development	Combine index of financial market and institutions indices	FD	The Financial Development Index by Syirydzenk (2016) and International Monetary Fund (2019)
Renewable energy	Renewable energy consumption per capita	REC	World bank (2019)
Globalization	Combine index of economic globalization, social globalization, political globalization	GB	The Swiss Institute of Technology in Zurich; Global Economy Website KOF (2019)
Institutional quality	Combine index of rule of law, control of corruption, voice and accountability, government effectiveness, regulatory quality, political stability, and absence of terrorism	IQ	World bank (2019) WDI
Gross domestic product	GDP constant of 2010 million dollars	GDP	World bank (2019)
Socioeconomic conditions	Index comprised of consumer price index, unemployment rate and poverty level	SEC	International Country Risk Guide (ICRG)

Appendix 3

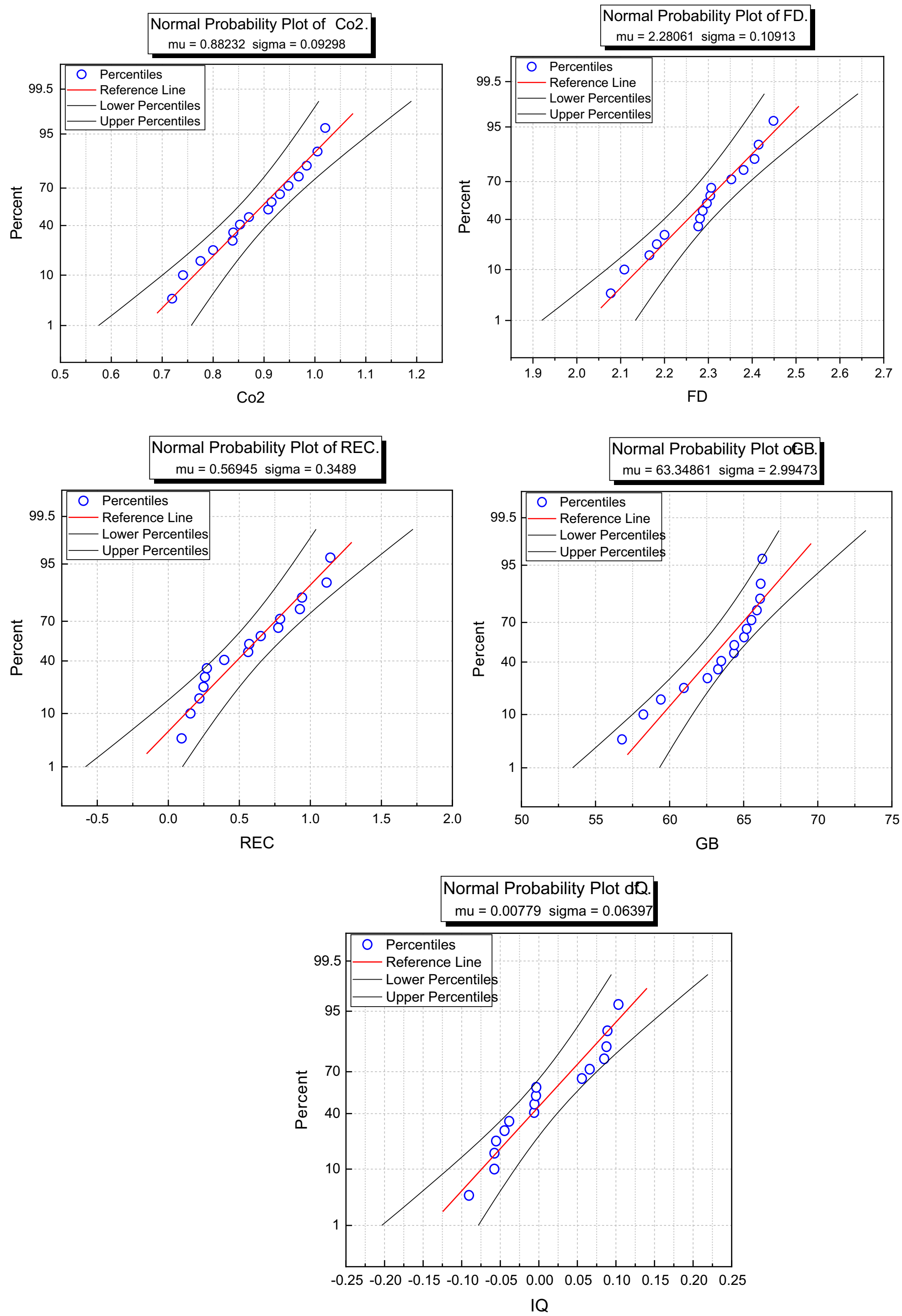

Fig. 3 Figures of normal distribution of variables

Appendix 4

Table 11 Time effect table (dependent variable: CO_2 emission)

Variables	Main model					Robust model				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
2003	Base year Omitted									
2004	–0.191	0.051			–1.933***	–0.224	–0.068			–5.676***
	(0.979)	(0.084)			(0.612)	(0.910)	(0.069)			(0.982)
2005	–0.418	0.144	0.105	0.097	–1.982***	–0.346	–0.093	0.106	0.062	–5.785***
	(0.980)	(0.133)	(0.083)	(0.081)	(0.628)	(0.912)	(0.097)	(0.083)	(0.080)	(0.989)
2006	–0.594	0.357*	0.201**	0.207**	–2.033***	–0.402	–0.020	0.202**	0.133	–5.871***
	(0.983)	(0.189)	(0.084)	(0.084)	(0.655)	(0.914)	(0.135)	(0.083)	(0.083)	(0.990)
2007	–0.791	0.404*	0.047	0.088	–2.153***	–0.504	–0.118	0.048	–0.024	–6.036***
	(0.986)	(0.224)	(0.084)	(0.090)	(0.670)	(0.916)	(0.182)	(0.084)	(0.088)	(0.993)
2008	–0.631	0.399	0.002	0.059	–2.149***	–0.363	–0.312	–0.003	–0.102	–6.101***
	(0.986)	(0.243)	(0.084)	(0.092)	(0.663)	(0.914)	(0.213)	(0.083)	(0.092)	(0.991)
2009	–0.443	0.192	–0.209**	–0.134	–2.187***	–0.265	–0.650***	–0.218***	–0.328***	–6.261***
	(0.986)	(0.264)	(0.084)	(0.092)	(0.653)	(0.913)	(0.226)	(0.084)	(0.095)	(1.003)
2010	–0.308	0.323	0.122	0.164*	–1.970***	–0.109	–0.635**	0.114	–0.069	–6.133***
	(0.990)	(0.272)	(0.084)	(0.096)	(0.672)	(0.916)	(0.281)	(0.084)	(0.102)	(1.017)
2011	–0.206	0.425	0.072	0.142	–1.933***	0.039	–0.683**	0.064	–0.128	–6.200***
	(0.992)	(0.298)	(0.084)	(0.099)	(0.680)	(0.917)	(0.319)	(0.084)	(0.108)	(1.032)
2012	–0.210	0.361	–0.028	0.055	–1.977***	0.053	–0.852**	–0.036	–0.243**	–6.281***
	(0.994)	(0.297)	(0.084)	(0.101)	(0.680)	(0.919)	(0.367)	(0.084)	(0.114)	(1.038)
2013	–0.246	0.294	–0.041	0.035	–2.048***	0.047	–1.054**	–0.050	–0.300**	–6.418***
	(0.994)	(0.303)	(0.084)	(0.102)	(0.687)	(0.920)	(0.405)	(0.084)	(0.121)	(1.049)
2014	–0.430	0.174	–0.072	–0.011	–2.129***	–0.220	–1.232**	–0.081	–0.367***	–6.521***
	(0.995)	(0.309)	(0.084)	(0.104)	(0.700)	(0.921)	(0.466)	(0.084)	(0.126)	(1.063)
2015	–0.528	0.126	–0.051	–0.005	–2.182***	–0.334	–1.409***	–0.065	–0.397***	–6.584***
	(0.994)	(0.306)	(0.084)	(0.105)	(0.700)	(0.920)	(0.466)	(0.084)	(0.131)	(1.067)
2016	–0.800	0.131	0.024	0.048	–2.266***	–0.459	–1.469***	0.011	–0.364***	–6.651***
	(0.993)	(0.304)	(0.084)	(0.106)	(0.701)	(0.921)	(0.499)	(0.084)	(0.135)	(1.067)
2017	–1.052	0.181	0.046	0.065	–2.315***	–0.683	–1.474***	0.034	–0.364***	–6.719***
	(0.994)	(0.317)	(0.084)	(0.109)	(0.712)	(0.921)	(0.537)	(0.084)	(0.139)	(1.081)
2018	–1.288	0.189	0.011	0.027	–2.406***	–0.752	–1.533***	–0.001	–0.417***	–6.836***
	(0.993)	(0.318)	(0.084)	(0.108)	(0.710)	(0.923)	(0.553)	(0.085)	(0.143)	(1.085)
Constant	–5.971***	5.182***	0.120	0.829	0.000	–10.194***	–7.817**	0.005	–2.798***	0.000
	(1.280)	(1.484)	(0.115)	(0.556)	(0.000)	(1.126)	(3.709)	(0.111)	(0.987)	(0.000)

Note: Standard errors in parentheses at 1% and 5% levels are ***$p < 0.01$ and **$p < 0.05$, respectively

References

Adeleye, N., & Eboagu, C. (2019). Evaluation of ICT development and economic growth in Africa. *NETNOMICS: Economic Research and Electronic Networking*, *March*. https://doi.org/10.1007/s11066-019-09131-6

Adger, N., & Coauthors including Fischlin, A (2018). Assessment report 5: Summary for policymakers. In *Planning for Climate Change: A Reader in Green Infrastructure and Sustainable Design for Resilient Cities* (Issues vii, 973, pp. 16–33). https://doi.org/http://www.ipcc.ch/publications_and_data/ar4/wg2/en/spm.html

Arellano M, Bover O (1995) Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics 68*(1):29–51. https://doi.org/10.1016/0304-4076(94)01642-D

Arminen H (2018) In the energy-growth nexus. In *The Economics and Econometrics of the Energy-Growth Nexus*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-812746-9/00010-9

Arminen H, Menegaki AN (2019) Corruption, climate and the energy-environment-growth nexus. *Energy Economics 80*:621–634. https://doi.org/10.1016/j.eneco.2019.02.009

Balsalobre-Lorente D, Shahbaz M, Roubaud D, Farhani S (2018) How economic growth, renewable electricity and natural resources contribute to CO2 emissions? *Energy Policy 113*(November 2017): 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bao C, Xu M (2019) Cause and effect of renewable energy consumption on urbanization and economic growth in China's provinces and regions. *Journal of Cleaner Production 231*(2019):483–493. https://doi.org/10.1016/j.jclepro.2019.05.191

Beggs JJ, Nerlove M (1988) Biases in dynamic models with fixed effects. *Economics Letters 26*(1):29–31. https://doi.org/10.1016/0165-1765(88)90046-8

Bhattacharya M, Awaworyi Churchill S, Paramati SR (2017) The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions. *Renewable Energy 111*:157–167. https://doi.org/10.1016/j.renene.2017.03.102

Blundell R, Bond S (1998) Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics 87*(1):115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Bond S (1991) Some tests of specification for panel data:monte carlo evidence and an application to employment equations. *Review of Economic Studies 58*(2):277–297. https://doi.org/10.2307/2297968

Carbon Footprint, (2018). Climate change. https://www.carbonfootprint.com/warming.html.

Cardenas LM, Franco CJ, Dyner I (2016) Assessing emissions-mitigation energy policy under integrated supply and demand analysis: The Colombian case. J Clean Prod 112:3759–3773. https://doi.org/10.1016/j.jclepro.2015.08.089

Chang CL, Ilomäki J, Laurila H, McAleer M (2020) Causality between CO2 emissions and stock markets. *Energies 13*(11):1–14. https://doi.org/10.3390/en13112893

Charfeddine L, Kahia M (2019) Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy 139*:198–213. https://doi.org/10.1016/j.renene.2019.01.010

Charfeddine, L., Yousef Al-Malk, A., & Al Korbi, K. (2018). Is it possible to improve environmental quality without reducing economic growth: Evidence from the Qatar economy. *Renewable and Sustainable Energy Reviews, 82*(July 2017), 25–39. Elsevier Ltd. https://doi.org/10.1016/j.rser.2017.09.001

Chin, H. (2017). *The belt and road initiative and its business implications*. *September*, 1–62.

Chin, H., Lau, F., He, W., & Cheung, T. (2015). The silk road economic belt and the 21st century maritime silk road. *Global Sourcing*, *Fung Busin*(May).

Cole MA (2007) Corruption, income and the environment: An empirical analysis. *Ecological Economics 62*(3–4):637–647. https://doi.org/10.1016/j.ecolecon.2006.08.003

Doytch N, Uctum M (2016) Globalization and the environmental impact of sectoral FDI. *Economic Systems 40*(4):582–594. https://doi.org/10.1016/j.ecosys.2016.02.005

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. *Economic Modelling 29*(4):1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Dutt K (2009) Governance, institutions and the environment-income relationship: A cross-country study. *Environment, Development and Sustainability 11*(4):705–723. https://doi.org/10.1007/s10668-007-9138-8

Eren BM, Taspinar N, Gokmenoglu KK (2019) The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. *Science of the Total Environment 663*:189–197. https://doi.org/10.1016/j.scitotenv.2019.01.323

Godil DI, Sharif A, Agha H, Jermsittiparsert K (2020) The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: new insights from QARDL approach. *Environmental Science and Pollution Research 27*(19): 24190–24200. https://doi.org/10.1007/s11356-020-08619-1

Gökmenoğlu K, Taspinar N (2016) The relationship between CO2 emissions, energy consumption, economic growth and FDI: the case of Turkey. *Journal of International Trade and Economic Development 25*(5):706–723. https://doi.org/10.1080/09638199.2015.1119876

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment author(s): Gene M . Grossman and Alan B . Krueger Reviewed work(s): *The Quarterly Journal of Economics*, *110*(2), 353–377.

Hao LN, Umar M, Khan Z, Ali W (2021) Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *Science of the Total Environment 752*:141853. https://doi.org/10.1016/j.scitotenv.2020.141853

HKTDC (2017) The belt and road initiative: Country profiles. *Hktbc 6*(2): 1–4

Hunjra AI, Tayachi T, Chani MI, Verhoeven P, Mehmood A (2020) The moderating effect of institutional quality on the financial development and environmental quality nexus. *Sustainability (Switzerland) 12*(9):1–13. https://doi.org/10.3390/su12093805

Ibrahim MH, Law SH (2016) Institutional quality and CO2 emission–trade relations: Evidence from Sub-Saharan Africa. *South African Journal of Economics 84*(2):323–340. https://doi.org/10.1111/saje.12095

IEA, & OECD. (2018). Update on recent progress in reform inefficient fossil fuel subsidies that encourages wasteful consumption. *G20 Energy Ministers' Meeting*, *June*, 13–14.

Jiang, C., & Ma, X. (2019). *The impact of financial development on carbon emissions : A global perspective*.

Jorgenson AK, Givens JE (2014) Economic globalization and environmental concern: A multilevel analysis of individuals within 37 nations. *Environment and Behavior 46*(7):848–871. https://doi.org/10.1177/0013916513479796

Kahia, M., Aïssa, M. S. Ben, & Lanouar, C. (2017). Renewable and non-renewable energy use - economic growth nexus: The case of MENA net oil importing countries. *Renewable and Sustainable Energy Reviews 71*(June 2015), 127–140. Elsevier. https://doi.org/10.1016/j.rser.2017.01.010

Khan A (2001) Financial development and economic growth. *Macroeconomic Dynamics 5*(3):413–433. https://doi.org/10.1017/s1365100500020046

Khan MTI, Yaseen MR, Ali Q (2017) Dynamic relationship between financial development, energy consumption, trade and greenhouse gas: Comparison of upper middle income countries from Asia, Europe, Africa and America. *Journal of Cleaner Production 161*: 567–580. https://doi.org/10.1016/j.jclepro.2017.05.129

Khan Z, Ali S, Umar M, Kirikkaleli D, Jiao Z (2020)Consumption-based carbon emissions and International trade in G7 countries: The role of Environmental innovation and Renewable energy. *Science of the Total Environment 730*:138945. https://doi.org/10.1016/j.scitotenv.2020.138945

Krammer SMS (2010) International R&D spillovers in emerging markets: The impact of trade and foreign direct investment. *Journal of International Trade and Economic Development 19*(4):591–623. https://doi.org/10.1080/09638190902792464

Lau LS, Choong CK, Eng YK (2014) Carbon dioxide emission, institutional quality, and economic growth: Empirical evidence in Malaysia. *Renewable Energy 68*:276–281. https://doi.org/10.1016/j.renene.2014.02.013

Li Z, Xu N, Yuan J (2015) New evidence on trade-environment linkage via air visibility. *Economics Letters 128*:72–74. https://doi.org/10.1016/j.econlet.2015.01.014

Mishkin FS (2009) Globalization and financial development. *Journal of Development Economics 89*(2):164–169. https://doi.org/10.1016/j.jdeveco.2007.11.004

NDRC, FM &, MC (2015) Vision and action for jointly building the silk road economic belt and the 21st century maritime silk road. Bo'ao Forum, Hainan

Ozatac N, Gokmenoglu KK, Taspinar N (2017) Testing the EKC hypothesis by considering trade openness, urbanization, and financial development: the case of Turkey. *Environmental Science and Pollution Research 24*(20):16690–16701. https://doi.org/10.1007/s11356-017-9317-6

Ozturk I, Acaravci A (2010) CO2 emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews 14*(9):3220–3225. https://doi.org/10.1016/j.rser.2010.07.005

Pérez K, González-Araya MC, Iriarte A (2017) Energy and GHG emission efficiency in the Chilean manufacturing industry: Sectoral and regional analysis by DEA and Malmquist indexes. *Energy Economics 66*: 290–302. https://doi.org/10.1016/j.eneco.2017.05.022

Pesaran, M. H. (2004). *Hqhudo 'Ldjqrvwlf 7Hvwv Iru &Urvv 6Hfwlrq 'Hshqghqfh Lq 3Dqhov. *University of Cambridge & USC*, *3*, Working Paper No.0435, June 2004.

Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*. *21*(August 2012):1–21. https://doi.org/10.1002/jae

Rahman MM, Velayutham E (2020) Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. *Renewable Energy 147*:399–408. https://doi.org/10.1016/j.renene.2019.09.007

Roodman D (2009) How to do xtabond2: An introduction to difference and system GMM in Stata. *Stata Journal 9*(1):86–136. https://doi.org/10.1177/1536867x0900900106

Sadorsky P (2011) Some future scenarios for renewable energy. *Futures 43*(10):1091–1104. https://doi.org/10.1016/j.futures.2011.07.008

Saud S, Chen S, Haseeb A (2018) Impact of financial development and economic growth on environmental quality : an empirical analysis from Belt and Road Initiative (BRI) countries. *Environmental Science and Pollution Research* 17

Saud S, Chen S, Haseeb A, Sumayya (2020) The role of financial development and globalization in the environment: Accounting ecological footprint indicators for selected one-belt-one-road initiative countries. *Journal of Cleaner Production 250*:119518. https://doi.org/10.1016/j.jclepro.2019.119518

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. In *Renewable and Sustainable Energy Reviews* (Vol. 25, pp. 109–121). Elsevier. https://doi.org/10.1016/j.rser.2013.04.009

Shahbaz M, Khan S, Ali A, Bhattacharya M (2017) The impact of globalization on CO2 emissions in China. *Singapore Economic Review 62*(4):929–957. https://doi.org/10.1142/S0217590817400331

Shahbaz M, Kumar Mahalik M, Jawad Hussain Shahzad S, Hammoudeh S (2019) Testing the globalization-driven carbon emissions hypothesis: International evidence. *International Economics 158*(July 2018):25–38. https://doi.org/10.1016/j.inteco.2019.02.002

Shahbaz M, Mallick H, Mahalik MK, Loganathan N (2015) Does globalization impede environmental quality in India? *Ecological Indicators 52*:379–393. https://doi.org/10.1016/j.ecolind.2014.12.025

Shahbaz M, Nasir MA, Roubaud D (2018) Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics 74*:843–857. https://doi.org/10.1016/j.eneco.2018.07.020

Shahbaz M, Solarin SA, Ozturk I (2016) Environmental Kuznets Curve hypothesis and the role of globalization in selected African countries. *Ecological Indicators 67*:623–636. https://doi.org/10.1016/j.ecolind.2016.03.024

Sheraz, M., Deyi, X., Ahmed, J., & Ullah, S. (2021). Moderating the effect of globalization on financial development , energy consumption, human capital, and carbon emissions : evidence from G20 countries. *Environmental Science and Pollution Research*, 1-19. https://doi.org/10.1007/s11356-021-13116-0

Tamazian A, Bhaskara Rao B (2010) Do economic, financial and institutional 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

Ullah A, Kui Z, Ullah S, Pinglu C (2021) Sustainable utilization of financial and institutional resources in reducing income inequality and poverty. Sustainability 13(3):1038. https://doi.org/10.3390/su13031038

Uzar U (2020) Is income inequality a driver for renewable energy consumption? *Journal of Cleaner Production 255*:120287. https://doi.org/10.1016/j.jclepro.2020.120287

Wang H, Chen Q (2014) Impact of climate change heating and cooling energy use in buildings in the United States. *Energy and Buildings 82*(2014):428–436. https://doi.org/10.1016/j.enbuild.2014.07.034

Wang R, Mirza N, Vasbieva DG, Abbas Q, Xiong D (2020) The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP 21 Agreements? *Journal of Environmental Management 271*(April):111027. https://doi.org/10.1016/j.jenvman.2020.111027

Wang Z, Danish Z, B., & Wang, B. (2018) The moderating role of corruption between economic growth and CO2 emissions: Evidence from BRICS economies. *Energy 148*:506–513. https://doi.org/10.1016/j.energy.2018.01.167

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). *Environmental Science and Pollution Research 26*(13):13246–13262. https://doi.org/10.1007/s11356-019-04761-7

Zaidi SAH, Zafar MW, Shahbaz M, Hou F (2019) Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia Pacific Economic Cooperation countries. *Journal of Cleaner Production 228*:533–543. https://doi.org/10.1016/j.jclepro.2019.04.210

Zhang YJ (2011) The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy 39*(4):2197–2203. https://doi.org/10.1016/j.enpol.2011.02.026

Zioło M, Kluza K, Kozuba J, Kelemen M, Niedzielski P, Zinczak P (2020) Patterns of interdependence between financial development, fiscal instruments, and environmental degradation in developed and converging eu countries. *International Journal of Environmental Research and Public Health 17*(12):1–17. https://doi.org/10.3390/ijerph17124425