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Determining the environmental effect of Chinese FDI on the Belt and Road countries CO_2 emissions: an EKC-based assessment in the context of pollution haven and halo hypotheses

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Abstract

This work aims to examines the effect of Chinese outward foreign direct investment (CoFDI), renewable energy, and energy intensity on CO_2 emissions in 46 Belt and Road Initiative (BRI) nations divided into: Panel A, consisting of 16 European countries, and Panel B, comprising 30 Asian and MENA countries. This analysis used data from 2005 to 2018, applying second-generation econometric techniques. The empirical outcomes, obtained using Driscoll–Kraay methods, confirmed the pollution halo effect in Panel A, suggesting that FDI flows in these countries are environmentally friendly. In contrast, the results indicated a positive impact of CoFDI on CO_2e in Panel B, supporting the pollution haven hypothesis that FDI may add to pollution. In addition, the study found an inverted-U-shaped association between per capita income and CO_2e, validating the environmental Kuznets curve (EKC) hypothesis in both panels. The findings also revealed that energy intensity positively affects CO_2e, whereas renewable energy has a significant negative effect in both panels, while the interaction terms of renewable and energy intensity are heterogenous in both panels. Based on these findings, the study recommends policy makers of these countries to attract clean FDI, particularly in renewable sectors, and shift from fossil fuel-based energy to renewable sources to control pollution by enacting energy-saving initiatives via lowering energy intensity.

Keywords CO_2e, Chinese outward FDI, Renewable energy, EKC, BRI

Introduction

A growing body of recent research—especially from environmental economists—has indicated that FDI may have negative environmental repercussions in addition to worries about global warming and climate change. According to the widely recognized pollution haven hypothesis (Phav-H), multinational corporations that engage in heavy pollution operations typically locate or establish their plants in developing countries with lax environmental restrictions. Consequently, these nations may see more pollution as FDI levels rise. However, many researchers revealed that by encouraging the use of energy-efficient technology and improved

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environmental management techniques, FDI had a positive effect on the environments of the host nations. Hence, there is a need for more research on this matter since the empirical literature is unable to produce a clear agreement regarding the impact of FDI on CO_2e. In the current state of the world, every country strives for greater economic growth (EG) for the benefit of its citizens. Nevertheless, rapid EG necessitates significant energy consumption (EC), which is harmful to the environment. Through the use of energy resources, FDI contributes significantly to EG, but it also has the potential to worsen the environment in the host nation. Though, fast globalization (trade liberalization and FDI), expanding industrialization, urbanization, and EC alter human lifestyles and raise possible environmental issues globally. Global EC increased dramatically between 1990 and 2014, from 1662.93 kg of oil equivalent to 1922.5 kg due to worldwide manufacturing [1]. According to the recent data from the BP Statistical Review of World Energy [2], the primary EC of the world accounted for 595.15 exajoules in 2021, with a growth rate of 5.8%, in which FF consumption (oil, gas, and coal) was dominant, while renewable energy was counting only 39.91 EJ. The amount of RE grew by more than 8 EJ between 2019 and 2021, however the FF consumption remained almost unchanged. Similarly, the CO_2e from energy were (33,884.059 Mt) with a growth rate of 5.917%.

Burning FF for transportation and energy are the main human activity that releases CO_2e into the atmosphere. Reducing CO_2e is essential for people's welfare because global warming have a wide range of potential physical, physiological, and ecological effects. These include increased sea levels, extreme weather events etc. [3]. Accordingly, due to the increasing trend in CO_2e, the goal of all researchers is to find an explanation for sustainable EG [1]. When it comes to addressing the problem of EQ, policymakers have determined that using renewable energy (RE) sources rather than FF is one of the most important solutions. To reduce their carbon footprint, a number of developed nations have worked to enhance their institutions and transition to more sustainable RE sources. The situation is different for a number of developing nations since their EG has historically depended on the use of FF, which has negatively impacted the EQ. Thus, raising the percentage of energy derived from RE sources is a vital policy goal for both developing and developed nations [4, 5].

In light of the above, this work aims to empirically check the environmental impact of CoFDI, energy intensity (EI), and RE in the BRI regions. Since the early 1990s, FDI has been a major factor in introducing new technology, assisting with developmental initiatives, increasing productivity, and promoting EG. In emerging economies, policymakers have witnessed fast EG accompanied by significant environmental degradation as a result of increased EC [1]. The research on the association between FDI, EC, EG, and the environment yields conflicting and ambiguous findings. There are two major hypotheses about EQ and FDI: the "Phav-H" and the pollution halo hypothesis "(Phal-H)." Numerous researches support the "Phav-H," which holds that FDI inflows have a worsen impression on the EQ [4–6]. While others support the "Phal-H" that FDI improves the EQ. For example [4, 5, 7], for the selected BRI nations confirmed the "Phav-H," by suggesting that FDI degrades EQ. On the other hand, for the panel of Central and South American (CSA) nations, found that FDI contributes to the reduction of CO_2e. Similarly [8], for a panel of 59 BRI nations indicated that FDI negatively cause CO_2e. In the literature, many studies, as mentioned above, checked the impact of total global FDI and its detrimental effect on the BRI country's EQ with inconclusive results. However, the effect of Chinese FDI (CoFDI) on BRI and its effect on EQ is mostly missing. Megaprojects like the BRI, which Xi Jinping has advocated since his official visit to Kazakhstan in 2013, undoubtedly have a significant and immediate impact on China's economic development, as well as the economies of the surrounding nations. However, it also has a negative influence on the environment due to CO_2e releases, which can put pressure on ecological life [9]. Since China planned a massive BRI project, the country is rising as a newly emerging global economy. Its mutual investment agreements affect sustainable development and environmental rights through international and regional FDI. In this regard, China is in a vital position to improve and promote international law and ecological principles and sustainable progress in the energy sector worldwide through this project in short time. China's bilateral investment treaties are expected to gain popularity as a model of investment in international trade, particularly in the areas of sustainable development and energy [10].

This work contributes to the body of literature by taking into account how these different factors (renewable energy, CoFDI, and energy intensity) affect the host BRI (Europe and Asia and MENA regions) country's sustainable environment within the setting of the EKC, the "Phal-H", or the "Phav-H" frameworks. Rationally choosing BRI is due to the fact that China plans to invest over a billion US dollars ($) in Africa, Asia, and Europe as part of the 'BRI' project. The BRI members account for 24% of global household consumers, 62.3% of the world's populace, 8.5% of the world's land area, and almost 30% of the global GDP. In addition, the majority of feasible CO_2 emitters are included in BRI [4, 5, 7]. This implies that the BRI nations have a big environmental impact that must be managed cautiously. BRI nations have recently attracted a lot of interest and seen economic success due to significant FDI flows, which have abundant natural resources, especially in terms of energy. Finally, to establish policies that are appropriate, it is imperative that the validity of the "EKC", "Phav-H", and "Phal-H" be looked at in BRI (in terms of CoFDI). The remaining paper is structured as follows chapter 2 reviews the literature, Chapter 3 consists of material and methods; Chapter 4 offers an empirical analysis and discussion; and Chapter 5 provides the study's conclusion, policy recommendations, and limitations.

Literature review

The social and environmental causes of FDI are of great concern. The debate seems to be increasing daily—whether FDI brings clean or dirty technologies to host nations presented by the "Phav-H" or the "Phal-H". In the present-day era of privatization and globalization, developed and developing countries have seen a massive inflow of FDI. Pollution steered by FDI has a long-term influence on rising levels of CO_2e, as discussed by many researchers. The "Phav-H" postulates that FDI flows to developing nations are increasing the levels of CO_2e . Various strands of literature focus on technology transfer (FDI) and environmental dilapidation in view of this hypothesis. The flow of FDI harms the environment, particularly in those nations that import pollution-intensive industries and have lax environmental regulations [6, 7, 11]. Even though this topic has been sufficiently researched, the literature appears to provide differing results. For instance, empirically, Sun et al. [12] supported the presence of "Phav-H" in China using the autoregressive distributed lag (ARDL) method, using data from 1980 to 2012. According to their empirical findings, a 1% rise in FDI inflow to China will surge CO_2e by 0.058%. Abdouli and Hammami [13] inspected the CO_2e, FDI, and EG association in 17 MENA nations using the panel VAR (vector auto-regressive) model. They suggested a feedback causality between FDI stock and CO_2e. Henceforth, FDI is considered the critical element for CO_2e. Sapkota and Bastola [14] inspected the influence of income and FDI on CO_2e for 14 Latin American nations using data from 1980 to 2010. They found evidence by confirming the EKC and Phav-H. Similarly, Rahman et al. [15], in their non-linear ARDL methods, confirmed both the EKC and Phav-H in Pakistan. In their study, established the presence of "Phav-H" in Cote d'Ivoire. Their ARDL results from utilizing data from 1980 to 2014 suggested that FDI, EC, and GDP per capita contribute to CO_2 discharges. Khan et al. [7], for the sample of BRI nations by utilizing data from 1990 to 2016, confirmed the "Phav-H" effect by suggesting that FDI degrades EQ. On the other hand [16], using ARDL methodology, suggested that FDI degrades the EQ in Brazil. Similarly, the fresh study of [1] used augmented mean group (AMG) and common correlated effect MG (CCEMG) suggested that FDI enhance EG while harming the environment in Brazil, Russia, India, China, and South Africa (BRICS).

Instead, according to the theory of "Phal-H", the inward FDI to a host nation brings the orientation of advanced and clean technologies that do not harm the local environment [6]. For instance, [17], in their empirical analysis using ASEAN countries panel data, specified that FDI inflow reduces CO_2e and thus supports the "Phal-H". Similarly, for the panel of CSA nations, found that FDI contributes to the reduction of CO_2e. Furthermore [8], from their estimated dynamic seemingly unrelated regression indicated that FDI has a robust negative long-term influence on CO_2e, in the panel of 59 BRI nations, thus supported the "Phal-H".

On the other hand, the positive association between EQ, EG, and EC has been established by many researchers so far. For example, examined the connotation between EC, GDP, and the environment in ten newly industrialized nations. They showed that an increase in EC and real income leads to an increase in ecological footprint. Similarly, Rahman et al. [15] also suggested that GDP and EC are the potential factors causing environmental degradation in six Asian nations. Furthermore, Gardiner and Hajek [18] found the feedback among GDP, EC, and CO_2e or the old European Union (EU) nations, whereas a one-way causation was noticed from GDP to EC and CO_2e in the new EU nations in the short term. In contrast [19], using 1985 to 2017 data for the United States (U.S) found that higher energy intensity adds to environmental pollution. Using FMOLS and DOLS methods [17] suggested that EC increases, while GDP decreases CO_2e in ASEAN. Similarly, Onifade et al. [20] for E7 nations used AMG, FMOLS, and DOLS and found that EG increased pollution during 1990 and 2016. Furthermore, the recent study of [4, 5] for 57 BRI nations, employing the Driscoll–Kray regression, indicated that FF energy increases, while RE decreases in CO_2e. Similarly, [4, 5] for BRICS suggested that coal consumption and EG increase in consumption-based CO_2e. While, [3] reported the connection between CO_2e, EG, RE, natural resources, and globalization in Columbia between 1970 and 2017. They suggested the growth-induced emissions using the FMOLS, DOLS, and ARDL methods. Globalization and RE, on the other hand, have shown a favourable influence on EQ. Ali et al. [21] analysed the potential effect of energy, FDI, innovation, and EG on CO_2e in the context of BRICS. From the AMG estimation, they supported the "Phav-H" while indicating that energy and EG were also the significant positive factors of CO_2e. Similarly, Rauf et al. [1], using AMG and CCEMG, found that EC creates environmental pollution in BRICS; likewise, EG increase in CO_2e. In the most recent studies, researcher like, [22] used ARDL method for V4 countries and found that renewable energy decline and GDP enhance CO_2, while FDI have no effect on EQ during period 1996 to 2022. Furthermore, [23] used different econometric methods and found that renewable substantially reduce emissions in OECD and MENA regions, while have insignificant effect on emissions in SAARC nations during 1998 to 2019. On the other hand, Wang et al. [24] from their moment quantile regression indicated that renewable energy substantially reduces ecological footprint in countries with lower quantile, while its impact is not prominent in nations with high quantiles.

As noticed above, various studies have addressed different factors responsible for EQ. Among various aspects, the total FDI–environment nexus is largely debated with inconclusive results. As per the authors' knowledge, previous work has considered the total FDI flows, or FDI flows only from a developed nation and its considerable impact on EQ (in a global panel of BRI). However, the FDI outflows from China (CoFDI), EI, RE, and its impact on the BRI nations' EQ (in the context of Europe and Asian and MENA regions) are considered negligible in the previous empirical literature. Thus, the present study will fill the existing gap in the literature by giving fresh insight into the limitations discussed above.

Materials and methods

Theoretical framework

Various measures and methods are available in the current literature to evaluate the importance of FDI in EQ. This work adopts a well-known EKC hypothesis as a baseline for analysing the environmental changes through CoFDI to BRI. As shown in Eq. 1, the EKC is a bell-shaped association between CO_2e and GDP per capita income (Y), and the square term of GDP (Y_{it}^2):

$$CO_{2eit} = \partial_0 + Y_{it} + Y_{it}^2 + \mu_{it} \quad (1)$$

Furthermore, energy intensity (EI_{it}) and renewable energy (RE_{it}) a potential increasing/decreasing factors for CO_2e, are included in Eq. 1 by deriving the following equation:

$$CO_{2eit} = \partial_0 + Y_{it} + Y_{it}^2 + EI_{it} + RE_{it} + \mu_{it} \quad (2)$$

The EKC is a hypothetical relation between income and the environment. The potential role of FDI in the EKC model is one of the essential variables for CO_2e, as suggested by previous researchers such as [12]. It has either an increasing or decreasing effect on the environment of host nations. Considering previous literature, the transmission of technology (FDI) causes EG and affects the environment. This phenomenon underlies the "Phal-H". Second, FDI may decrease CO_2e via technological innovations that align with the "Phav-H". By incorporating CoFDI, the following equation is derived:

$$CO_{2eit} = \partial_0 + Y_{it} + Y_{it}^2 + EI_{it} + RE_{it} + CoFDI_{it} + \mu_{it} \quad (3)$$

The below-specified model is derived within the modification of the prior studies of [11, 25] for the empirical analysis in the log-linear form as

$$\ln CO_{2eit} = \partial_0 + \beta_1(\ln Y_{it}) + \beta_2(\ln Y_{it})^2 + \beta_3(\ln CoFDI_{it}) + \beta_4(EI_{it}) + \beta_5(RE_{it}) + \mu_{it} \quad (4)$$

where the natural log of the variables is presented with ln and μ_{it} denotes error term, where FDI-led emissions (dirty or clean technologies transfer) are checked based on "Phal-H" or "Phav-H", income-led emissions the EKC, and energy-led emissions.

The study's variables have a range of implications and align with prior hypotheses and research. In Eq. 4, the CO_2e are a proxy for EQ as the dependent variable, coordinated with [1, 4, 5]. According to the statistical data from World Bank, global CO_2e have increased dramatically over the last two decades, with a notable surge from 22,149.4 million tons in 1990 to 36,390.3 mt in 2018 [26]. The majority of research has evaluated EQ using CO_2e. Both higher and lower levels of CO_2e are correlated with EQ: higher CO_2e means poorer EQ, whereas lower CO_2e means higher levels of EQ [1]. Mostly, CO_2e, which account for over 80% of GHG emissions that create catastrophic calamities, are generally from the burning of FF, which are used to produce energy [16]. The coefficient for explanatory variables such as GDP per capita (lnY) is probable to have a positive sign, thus $\beta_1 > 0$, whereas for GDP per capita square $(\ln Y)^2$ will have a negative sign thus $\beta_2 < 0$, in line with [16], thus it indicates an inverted U-shaped connotation, between CO_2e and income. The coefficient of (lnCoFDI) will have either positive or negative signs, $\beta_3 < 0$ or $\beta_3 > 0$, according to the "Phal-H" or "Phav-H". The coefficient of (EI) has an expected positive sign thus $\beta_4 > 0$. The amount of energy used in production is known as energy intensity. Energy is necessary for achieving both basic necessities and the objectives of EG; nonetheless, if energy generation relies on FF, an increased EI could cause environmental damage [19]. The coefficient of (RE) will have an expected negative sign. As discussed earlier, FF are the main factor behind pollution, while RE may help curb CO_2e; thus, β_5 is < 0. Overall, all are dissimilar to previous studies that used total energy in the BRI context; instead, we take into account EI similar to and renewable energy consistent with [4, 5]. The conceptual framework of the link between CoFDI, income, energy, and EQ is shown in Fig. 1. The mainstream literature suggests that these factors affect EQ in dissimilar ways, as suggested by [1] that FDI increase EG, but on the other hand, it degrades EQ. FDI is measured by country-to-country technology transfer [27], the theory that foreign corporations can contribute to rich knowledge of the host countries forms the basis of the spill over impact of FDI on EG, and as a result play important role in innovation of technology [28]. Although [11] indicated that an upsurge in per capita first increase in pollution but reaching a threshold/ turning point a further rise in income improve EQ that is line with "EKC" hypothesis. Similarly, [4, 5] suggested that FF degrade, while RE improve EQ.

Data

The data are extracted for the sample of 46-BRI nations (presented in Table 8, Appendix) for the period 2005–2018 from the World Bank [29], Global Carbon Atlas [30], and the Statistical Bulletin of China's Outward Foreign Direct Investment [31] yearbook. The time and sample are chosen owing to the availability of data. The BRI samples were split into two groups, i.e., Europe indicated by Panel A, and other nations from Asia plus the Middle East and North African (Asia + MENA) regions, indicated by Panel B. The dependent variable is carbon emissions (CO_2 in metric tonnes), reliable with [4, 5, 7]. Explanatory variables consist of Chinese outward FDI stock in million US$ as a proxy for Chinese outward (CoFDI) in BRI consistent with [32]. The stock variable in environmental literature is also compatible with [13]. Economic growth is indicated by GDP per capita (Y) at constant 2015 US$ and a square term of Y per capita, consistent with [16]. Renewable energy (RE) is % of the total final EC consistent with [4, 5, 33]. Finally, the energy intensity (EI) level of primary energy (MJ/$2017 PPP GDP) is used, similar to [19]. The variables unit's definition and source are given in Table 9 in Appendix. Table 1 presents the description of all the data. It is evident from the data that the highest CO_2e were indicated in Panel B, with high Chinese FDI flows and a minimum of 0% renewable energy use in some MENA countries that are highly FF dependent. The countrywise dynamics of the variables are shown in Fig. 2 for 'Panel A', while Fig. 3 shows the dynamics of variables for 'Panel B'.

Table 1 Descriptive statistics

Variables	Mean	St. Dev	Min	Mix
Panel A				
CO_2e	3.507	1.680	1.359	7.444
CoFDI	3.093	2.453	−0.693	9.561
Y	8.856	0.689	7.559	9.887
EI	4.999	1.740	2.520	11.08
RE	19.26	11.37	1.270	42.60
Panel B				
CO_2e	4.175	1.544	0.840	7.883
CoFDI	5.766	2.132	−0.673	10.82
Y	8.515	1.371	6.254	11.20
EI	5.085	2.177	1.650	19.33
RE	21.88	25.39	0.000	91.31

CO_2e environmental degradation, *CoFDI* Chinese outward FDI, *Y* GDP capita and all of these variables are in natural log, while *EI* energy intensity, and *RE* renewable energy consumption

Methodology

Panel data predominantly suffer from serial correlation (SC) and cross-sectional dependence (CD). If ignored, the CD problem can cause inaccuracy, bias, and inconsistency in the estimation. Therefore, this

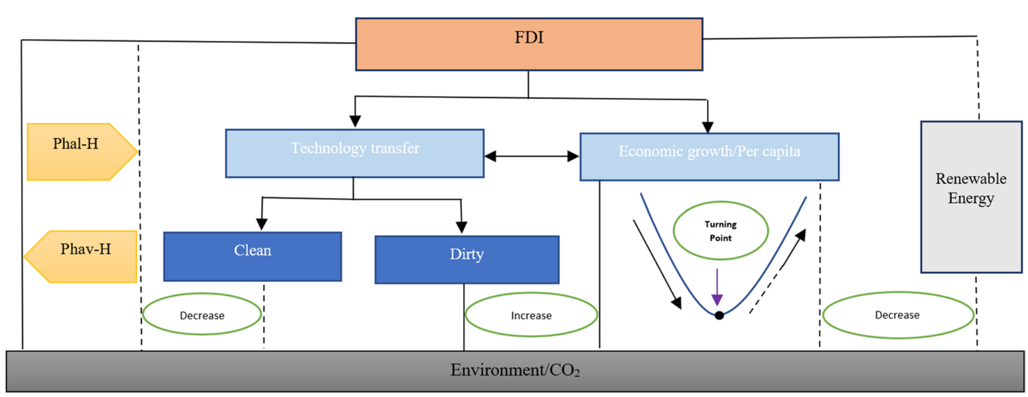

Fig. 1 Mechanism of investment and other factors with the environment: derived from [12]

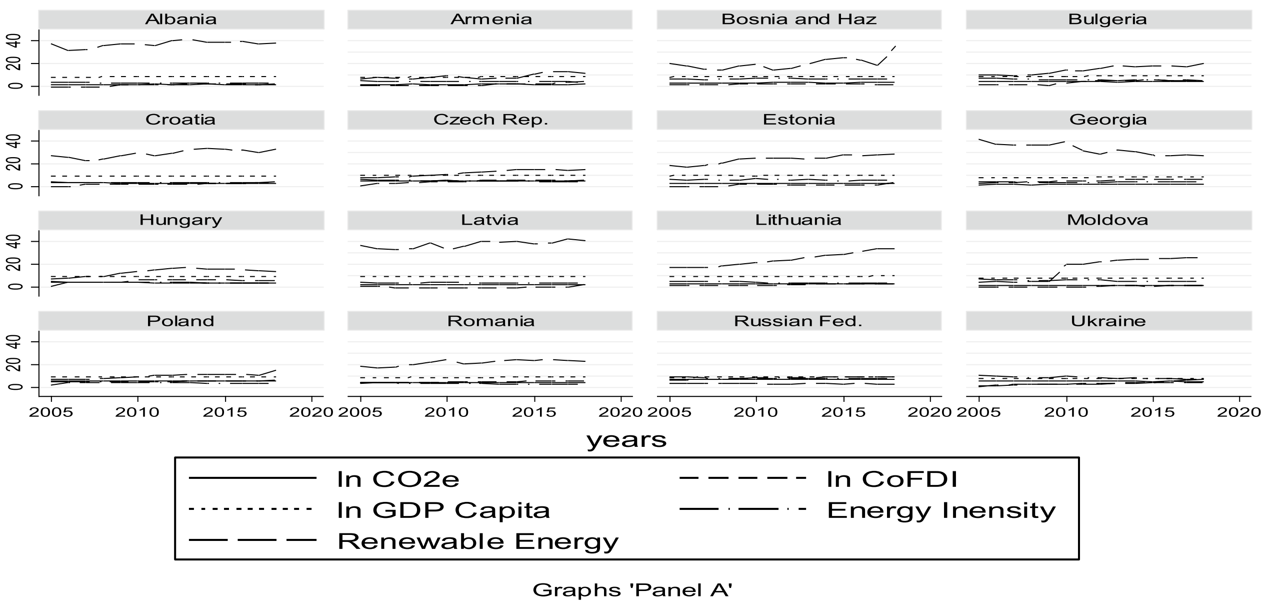

Fig. 2 Trend in variables for 'Panel A'

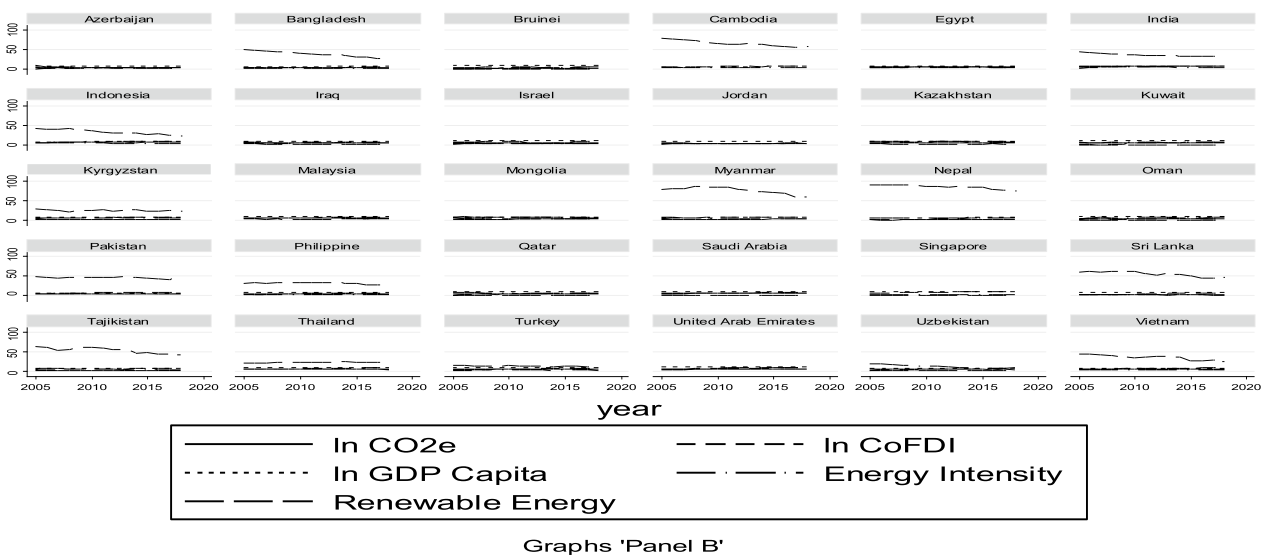

Fig. 3 Trend in variables for 'Panel B'

work adopts the CD test given by Pesaran [34] to find the CD across the panels prior testing for unit roots in the data. Besides CD, if the slopes are not homogenous, estimating on the premise of slope homogeneity yields deceptive results. Therefore, controlling the slope heterogeneity is essential for empirical evaluations of the data [11]. The current work used the tests of slope homogeneity, which allow for large N and T in light of the above concerns. Furthermore, due to limitations, like when data have CD, the second-generation unit root test recommended by [35] is better than the first-generation unit root test, so we used the [35] test. After addressing the issues of CD and unit roots, the selected variables are examined for a long-term association in the next step using the [36] test that considers CS and heterogeneity [27]. Because of the presumed

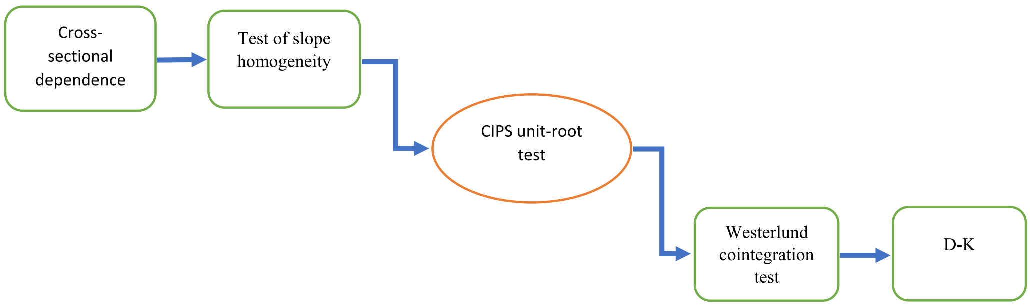

Fig. 4 Schema of methodologies

Table 2 Cross-sectional dependence tests results

	CO_2e	*Y*	CoFDI	EI	RE
Panel A					
Pesaran CD	6.470	30.31	27.47	23.21	16.99
P values	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel B					
Pesaran CD	49.51	33.17	66.26	22.85	4.61
P values	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Ho weak CD, H_1 strong CD

CD across the panels, the traditional cointegration tests (i.e., Pedroni or Kao, etc.) may not be able to produce reliable and objective conclusions in cases of CD in the data [11].

Furthermore, for the long-term coefficient, we used the most common methods in panel data analysis, the random effects (RE) and fixed effects (FE) models for compression between FE or RE, which we checked via the Hausman test. However, the proposed test of Pesaran suggested the presence of CD. Thus, we used regression with Driscoll–Kraay (1998) standard error. This estimation, indicated by D–K, deals with problems of CD, autocorrelation, and heteroskedasticity. Besides, it permits the performance of FE in the estimation [37]. When heteroscedasticity and serial and spatial dependency are possible, D–K is regarded as one of the best methods. Moreover, the D–K covariance estimator can handle missing values and is applicable to the data both unbalanced and balanced [4, 5]. The general schema of methodologies used for the analysis is presented in Fig. 4.

Empirical results and discussion

Empirical results

The results of Pesaran CD are shown in Table 2. The test is conducted with the null hypothesis (Ho) that there is no CD. These findings have established the presence of CD at a 1% significance level. It suggests that an impulse to the data in one economy can run over to others by influencing the practice and policies in the overall panel.

Table 3 Slope homogeneity test results

Panel A	Delta	*P*. value	Panel B	Delta	*P*. value
P	2.706	0.007	*P*	11.022	0.000
adj	3.827	0.000	adj	14.581	0.000

H0: slope coefficients are homogenous

Table 4 Pesaran (CIPS) unit-root tests results

	Panel A		Panel B	
	At level	At first diff	At level	At first diff
CO_2e	−1.175	−3.705*	−2.214**	−3.593*
CoFDI	−2.403**	−3.413*	−2.351*	−3.634*
Y	−1.949	−2.080**	−2.194**	−2.586*
EI	−2.799*	−3.919*	−2.040	−3.289*
RE	−1.796*	−2.705*	−1.709	−2.823

*, ** Indicates a 1% and 5% level of significance

Furthermore, the slope homogeneity test results shown in Table 3 have also shown that there is country-specific heterogeneity in the data and has rejected the Ho.

To observe the stationary of the series, we employed the Pesaran panel unit root test with CS, and the outcomes are obtainable in Table 4, indicating the rejection of unit roots. The outcomes show that the variables under consideration were non-stationary at levels; though, when the first difference is computed, all of the series become stationary, indicating that all the variables under consideration had first-order integration.

Furthermore, after checking the unit root, we check for the long-run cointegration among the variables in the next step. Evidence from the Ho of Westerlund test presented in Table 5 is accepted; thus, there is no cointegration indicated in the data.

Table 5 Westerlund cointegration test results

	Statistic	*P* value	Statistic	*P* value
Panel A			Panel B	
Variance				
Ratio	− 0.5818	0.2803	− 1.1416	0.1268

Ho: No cointegration, Ha: some panels are cointegrated

Discussion

Table 6 represents the long-term Driscoll–Kray results within FE and RE, while the Hausman specification test results with probability Chi-square are given at the end of Table. In both Panels A and B, the positive coefficients of (GDP per capita) and a negative coefficient of the square of income established the EKC hypothesis in BRI regions per the results of [11]. The EKC is an upturned U-shaped linkage between income and CO_2e. Conferring to this, environmental pollution starts with an upsurge in EG. When income rises, it reaches a threshold turning point, and after ecological degradation improves [6]. With a rise in income, the public demands for a clean environment also rise, which grosses the implementation of new policies, laws, and rules to preserve the environment and, thus, diminishes environmental contamination [11].

Furthermore, the coefficient of Chinese outward FDI is heterogeneous for both panels. Its coefficient bears a positive sign for Panel B (consisting of Asia plus other MENA nations), indicating that a 1% increase in CoFDI to these BRI regions rises in CO_2e up to (0.065–0.067%) consistent with the "Phav-H" theory. This finding is maintained by [11], who originated that total FDI flow to 54-BRI nations positively impacts their ecological footprints by holding "Phav-H". From the empirical findings, it is clear that China's investment is not green in some countries as China himself is among one of the top CO_2 emitters. suggested that CoFDI creates environmental pollution in BRI nations. The results obtained by [38] also confirmed that China became "Phav-H" for few developed nations and some developing nations became "Phav-H" for China. It was suggested by [9] that implementing BRI generated an industrial rise in China's economy, which can significantly degrade its environment by releasing CO_2e in the near future. Chinese leaders require to address the issue of industrial waste to avoid environmental pollution. This step will ensure China's sustainable development in the future and yield very effective results under the BRI project. These outcomes are also related to the past results by [1].

More so, the coefficient of CoFDI is negative for Panel B, consisting of European BRI nations. Keeping other aspects constant, a 1% increase in FDI flow to Panel A will decrease pollution by (0.0039 to 0.0031%). The findings signify that CoFDI toward Europe does not significantly harm their environment, thus confirming the "Phal-H" effect. This outcome suggests that Europe attracts innovative, high-quality, and environmentally

Table 6 Long-run results of the estimated models

Variable	DK–FE			DK–RE		
	Coeff.	Drisc/Kray std. err.	Prob.	Coeff.	Drisc/Kray std. err.	Prob.
Panel A						
Y	2.7970	0.3585	0.000	2.7715	0.6156	0.000
Y^2	− 0.1318	0.0197	0.000	− 0.1286	0.0322	0.002
CoFDI	− 0.0039	0.0019	0.069	− 0.0031	0.0048	0.071
EI	0.1207	0.1262	0.000	0.1256	0.0138	0.000
RE	− 0.0109	0.0007	0.000	− 0.0112	0.0014	0.000
_Con	− 12.856	1.6175	0.000	− 12.678	2.7768	0.001
Prob > Chi^2			0.989			
Panel B						
Y	2.8153	0.5627	0.000	2.8820	0.6345	0.001
Y^2	− 0.1239	0.0283	0.001	− 0.1316	0.0304	0.001
CoFDI	0.0650	0.0672	0.000	0.0672	0.0140	0.000
EI	0.0885	0.0071	0.000	0.0842	0.0059	0.000
RE	− 0.0068	0.0019	0.003	− 0.0071	0.0023	0.009
_Con	− 11.255	2.6936	0.001	− 11.243	2.9729	0.002
Prob > Chi^2			0.1321			

CoFDI Chinese outward FDI, *Y* GDP capita and all of these variables are in the natural log, while *EI* energy intensity, and *RE* renewable energy consumption. Panel A consists of the European region, and Panel B includes other Asia and MENA regions friendly investments due to its possible strict and effective environmental regulations. The EU is a pioneer in supporting carbon reduction policies and innovations, but also because there are already well-defined tight regulations on polluting activities. Indeed, EU emissions should be reduced by 80 to 90% by 2050, relative to 1990 levels [37]. Similarly, [39] indicated that EU FDI could encourage energy efficiency through innovation in technology and decreasing CO_2e. Similar to these findings, [17] obtained the same results for ASEAN nations, that FDI depress CO_2e.

In addition, the coefficient of control variable energy intensity (EI) for both Panels A and B has a noteworthy positive effect on the BRI country's environment. Our finding is consistent with Liu and Bae [40] for China and [19] for the U.S. The result indicates that energy is a prime factor for emissions as these nations included in BRI are potential consumers of energy that have not fully adopted the usage of green energy, especially in some MENA nations. Economic development founded on the severe use of energy and FDI in dirty technologies has created pollution in most BRI nations [7]. Earlier studies by Khan et al. [11], also signify that energy use leads to CO_2 in 54 BRI nations. Furthermore, Ahmad et al. [27] showed that FDI flow and total EC increase CO_2e in the panel of OECD nations. Our empirical result implies that although FDI is essential for GDP growth, it also adds to CO_2e in some nations. This result is further upheld by [1] for BRICS. In the interest of globalization, most developing countries are keen to attract a large sum of FDI but without adequate environmental supervision. Conversely, the coefficient of renewable energy is highly significant and negative for both panels. Recommending that RE helps in combating pollution emissions. Similar to our finding, Xu et al. [41] for G20 found that GDP per capita and FF have a positive connotation with GHG emissions, where RE has a negative correlation with GHG. This outcome also agrees with the findings of [3] for Colombia.

Finally, the robustness of the outcomes is checked by including the interaction terms of energy intensity with renewable energy (EI*RE) by estimating a separate model, and the outcomes are presented in Table 7. All the results (coefficients) offered in Table 7 are matched and consistent with the baseline model estimations in (Table 6). CoFDI positively affects the BRI nation's environment in Panel B by supporting "Phav-H". Panel A has a negative CoFDI effect that signifies the "Phal-H" effect. The coefficient of EI*RI suggests heterogeneous signs in both regions. It can signify that European region use energy efficiency and clean technologies (renewable) to combat pollution control. In Panel B, the countries are from Asia and MENA, which mostly are highly dependent on FF sources. Thus, the ratio of RE to FF is still less. Based on empirical findings, these countries' policymakers are suggested an increasing the level of RE and decreasing the consumption of FF to help combat pollution emissions. Markets for RE have lately emerged in BRI participant nations. However, these nations contribute very little to global investments in RE, even though they have an abundance of RE resources [42]. This finding supports the idea that using FF might have a negative impact on EQ, and similar findings have been reported in the current research of [33] for African oil-producing nations. They indicated that the production and use of FF have increased due to these nations'

Table 7 Robustness check

Variable	DK–FE			DK–RE		
	Coeff.	**Drisc/Kray std. err.**	**Prob.**	**Coeff.**	**Drisc/Kray std. err.**	**Prob.**
Panel A						
Y	5.3329	0.6718	0.000	5.3696	0.9276	0.000
Y^2	−0.2829	0.0372	0.000	−0.2852	0.0507	0.000
CoFDI	−0.0319	0.0045	0.000	−0.0299	0.0073	0.001
EI*RE	−0.0179	0.0002	0.000	0.1256	−0.0018	0.000
_Con	−21.147	3.0212	0.000	−21.290	4.0719	0.001
Prob > Chi^2			0.9937			
Panel B						
Y	3.4504	0.0133	0.000	3.5316	0.6401	0.000
Y^2	−0.1709	0.0255	0.000	−0.1770	0.0296	0.000
CoFDI	0.0624	0.0133	0.000	0.0632	0.0134	0.000
EI*RE	0.0006	0.0005	0.286	0.0842	0.0005	0.245
_Con	−12.908	2.5460	0.000	−13.147	3.0760	0.001
Prob > Chi^2			0.7830			

CoFDI Chinese outward FDI, *Y* GDP per capita and all of these variables are in the natural log, while *EI*RE* the interaction of energy intensity and renewable energy inclusion into the global economy. Their economies' most energy-intensive industries, such as manufacturing and transportation, rely heavily on FF-powered technology for things like cars and other machinery.

Conclusion and policy suggestions

The prime objective of this work was to observe the Chinese FDI toward BRI nations and its possible impact on these nations' environmental quality. Overall, the application of second-generation methodology was used for data analysis. The Driscoll–Kraay method is employed for the long-term estimation. The empirical results confirmed the pollution haven hypothesis for Panel B, consisting of Asia plus MENA nations. The empirical results disclosed that the environmental degradation of these nations may rise with an increase in the CoFDI. Together, the outcomes confirm the pollution halo effect for the group of Panel A consisting of the European region, indicating that due to their possible strict environmental regulation, these countries attract innovative and clean investments. The EKC hypothesis—which holds that economic expansion has a decreasingly negative effect on CO_2e over time—is also confirmed. The empirical results also validated the positive effect of energy intensity on CO_2e and the negative effect of renewable energy on CO_2e.

Policy implications and limitations

The study's conclusions offer empirical support for how these variables influenced the environmental outcomes of the BRI and have ramifications for stakeholders and policymakers tackling environmental issues, including climate change and global warming. The link between CO_2e, energy, FDI, and GDP factors is vital as regards sustainable strategies since these factors are intensely elastic under macroeconomic policies. Henceforward, the enhanced exposition is to expand green financing opportunities through CoFDI, green energy sources, and sustainable growth of the BRI nations. The financial organizations in BRI should enhance investment in technologies that can offer the foundation for efficient energy patterns in the future to guarantee a sustainable growth pathway. Thus, BRI should further launch and enhance the environmental supervision and management system for CoFDI inflows to less strict ecological regulation nations in Asia and Africa. The findings call for formulating effective policies to inspire CoFDI toward green investment in renewable energy sectors. BRI nations may consider pulling CoFDI by instigating environmental guidelines to control CO_2e. In addition, these countries' governments ought to enact energy-saving initiatives and inspire the usage of renewable energy sources by lowering energy intensity and lessening reliance on FF. If energy intensity is effectively reduced, it can significantly meet basic needs and accomplish sustainable development objectives. Policy analysts should support R&D spending and innovation to raise the quality of environment and efficiency of energy.

The limitations of this study relate to the studied sample, which only contains 46 BRI nations. Possibly, forthcoming research can reconsider all countries recently joining the BRI. Second, instead of using the more common variable, CO_2e proxied for the environmental quality, in future research work, indicators such as ecological footprints and other GHG emissions can be used—furthermore, the EKC inverted U-shaped needs additional discussion with multiple turning points, N-shaped, W-shaped, or M-shaped.

Appendix

See Tables 8, 9.

Table 8 Selected 46 sample nations used in the Analysis

Panel A					
Albania	Armenia	Bosnia and Haz	Bulgaria	Croatia	Czech Rep
Estonia	Georgia	Hungary	Latvia	Lithuania	Moldova
Poland	Romania	Russian Fed	Ukraine		
Panel B					
Mongolia	Brunei	Cambodia	Indonesia	Malaysia	Myanmar
Philippine	Singapore	Thailand	Vietnam	Kazakhstan	Kyrgyzstan
Tajikistan	Uzbekistan	Egypt	Iraq	Israel	Jordan
Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates	Bangladesh
India	Nepal	Pakistan	Sri Lanka	Azerbaijan	Turkey

Selected 46 nations out of 65 BRI countries and beyond. More about the classification of BRI can be found on https://greenfdc.org/countries-of-the-belt-and-road-initiative-bri/

Table 9 Variable, unit and sources

Variable	Unit and measurement	Sources
CO_2/proxy for EQ	Million tonnes (Mt)	Global Carbon Atlas. http://www.globalcarbonatlas.org/en/CO2-emissions
Chinese outward FDI (CoFDI)	Chinese total FDI stock in millions USD	Statistical Bulletin of China's Outward Foreign Direct Investment (2016). And United Nations Conference on Trade and Development (2018)
GDP (Y)/ per capita	Constant 2015 USD	World Development Indicators. https://datacatalog.worldbank.org/dataset/world-development-indicators
Renewable energy consumption (RE)	% of total final energy consumption	World Development Indicators. https://datacatalog.worldbank.org/dataset/world-development-indicators
Energy intensity (EI)	Primary energy (MJ/$2017 PPP GDP)	World Development Indicators. https://datacatalog.worldbank.org/dataset/world-development-indicators

Abbreviations

FDI	Foreign direct investment
CoFDI	Chinese outward FDI
CO_2e	Carbon dioxide emissions
BRI	Belt and Road Initiatives
EQ	Environmental quality
EI	Energy intensity
RE	Random effect
EKC	Environmental Kuznets curve
FF	Fossil fuel
MENA	Middle East and North African
GHG	Greenhouse gases emissions
D–K	Driscoll–Kraay
RE	Renewable energy
CD	Cross-sectional dependence
Phav-H	Pollution haven hypothesis
Phal-H	Pollution halo hypothesis
EG	Economic growth
EG	Energy consumption
GDP	Gross domestic product
FE	Fixed effect
PPP	Purchasing power parity

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Availability of data and materials

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