

A Study on the Carbon Emission Effects of China's OFDI in Belt and Road Countries

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Abstract: The Belt and Road Initiative (BRI), proposed by China in 2013, is a major global initiative aimed at fostering economic development and connectivity. However, relevant data indicate that some BRI countries rank among the highest in global carbon emissions, raising international concerns about the environmental impacts of China's outward foreign direct investment (OFDI). Based on panel data from 62 BRI countries spanning the years 2003 to 2023, this paper explores in depth the impact of China's OFDI on carbon emissions in these countries. The results show that: (1) China's OFDI significantly reduces carbon emissions in BRI countries, demonstrating a "pollution halo" effect. Additionally, the impact of China's OFDI varies across countries with different levels of carbon emissions; (2) China's OFDI curbs carbon emissions mainly by promoting technological innovation and enhancing government effectiveness; (3) Heterogeneity analysis reveals that China's investments in OECD and developed countries under the BRI show a more pronounced carbon reduction effect. Moreover, the carbon mitigation impact of China's OFDI differs between neighboring and non-neighboring countries. Therefore, China should continue to deepen cooperation with BRI countries and develop targeted investment strategies based on the economic development level, trade openness, and geographical location of each country. Emphasis should be placed on strengthening mechanisms for the sharing of green technologies and improving governance capacity among participating countries.

Keywords: Outward Foreign Direct Investment, Carbon Emissions, Technological Innovation, Government Effectiveness, Belt and Road Initiative

1. Introduction

According to the latest global greenhouse gas emissions data released by the World Bank, more than half of the top ten emitting countries are located along the Belt and Road Initiative (BRI) route. Against this backdrop, some international discourse has wrongly accused China's outward foreign direct investment (OFDI) of shifting domestic pollution abroad in order to reduce its own carbon emissions. This view not only misrepresents the nature of China's investments but also overlooks the positive environmental impacts that China's OFDI can have on host countries. It is important to note that the low-carbon development of BRI countries is influenced by a variety of factors—such as technological advancement, energy consumption, and industrial structure—and attributing high emissions solely to China's OFDI is one-sided and unjustified [1]. Given this context, how does the carbon emission effect of China's OFDI vary across BRI countries with different levels of trade openness, economic development, and geographical location? What are the specific mechanisms

through which these effects occur? Answering these questions not only contributes to the advancement of a green BRI but also provides valuable insights for promoting the low-carbon and clean development of China's overseas investments, thereby supporting global green economic recovery and the construction of ecological civilization worldwide.

The possible marginal contributions of this paper are as follows: First, it offers an innovative research perspective. On the one hand, the study focuses on China—as both the initiator of the BRI and the world's largest developing country—by exploring the impact of China's OFDI on the carbon emissions of BRI countries. On the other hand, while most domestic studies concentrate on the environmental impact of OFDI on the home country, few have examined its effects on the ecological environment of recipient countries. Second, it contributes to theoretical innovation. Drawing on existing theories, this paper delves into the internal mechanisms through which OFDI influences carbon emissions, with particular emphasis on technological innovation and government governance capacity, thereby enriching the theoretical framework surrounding the carbon emission effects of OFDI. Third, through empirical analysis, this paper demonstrates the existence of China's green investment practices, providing robust evidence to counter the unfounded “environmental threat” narrative often propagated by Western media regarding China's OFDI. Furthermore, the findings offer empirical support for China's continued promotion of green OFDI and for assisting BRI countries in achieving their dual carbon goals.

2. Literature review

Since COPELAND and TAYLOR developed a static model of North-South trade to study the relationship between trade and the environment, the linkage between an open economy and environmental outcomes has gradually become a central focus in academic research. Regarding the environmental effects of outward foreign direct investment (OFDI), some scholars believe that foreign direct investment is a significant factor influencing environmental quality. However, there is no consensus on how exactly it affects the environment, and several divergent viewpoints have emerged.

One perspective is the “pollution haven” hypothesis, which suggests that incoming foreign investment exacerbates environmental pollution. Classical international trade theory posits that, due to comparative advantages, capital generally flows from developed countries to developing ones. Compared to developed countries, developing countries often have lower environmental standards. As a result, some developed countries relocate highly polluting industries to these regions through international investment, thereby causing environmental degradation in the host countries. Moreover, some scholars argue that certain developing countries may engage in a “race to the bottom” by lowering environmental standards to enhance competitiveness and attract foreign capital [2,3]. Numerous studies have validated the pollution haven hypothesis. For example, Sun et al. analyzed data on multinational capital inflows into China's secondary sector and found that these industries attracted large amounts of foreign direct investment, which in turn intensified environmental pollution in China [4]. Based on a sample of 30 Chinese provincial-level administrative units, Li Zihao and Dai Dier concluded that FDI has a significant impact on increasing carbon emissions [5]. Focusing specifically on China and countries along the Belt and Road, some scholars believe that China's energy investments in BRI countries are dominated by energy-intensive and highly polluting industries, leading to an increase in carbon emissions in these host countries [6].

Another perspective is the “pollution halo” hypothesis, which asserts that foreign investment can improve environmental quality. Through green technology spillovers and the diffusion of advanced low-carbon production techniques and environmentally friendly management systems, multinational corporations can help improve local environmental conditions [7,8]. Based on panel data from 168 countries (or regions) between 2003 and 2014, Liu Yubo and Wu Wanzong found that China's OFDI

significantly reduced pollutant emissions, enhanced energy efficiency in host countries (or regions), and improved local environmental quality [9]. Zheng Qiang and others also found that OFDI significantly improves the environmental quality of investment recipient countries [10]. With a specific focus on China and BRI countries, Li Xiaxiang et al. concluded that China's OFDI contributes positively to both economic growth and carbon reduction in BRI regions, and that this positive effect becomes more pronounced as the scale of investment increases [11].

The validity of these two hypotheses largely depends on the specific research objectives and contextual background. Sheng Bin et al. argue that FDI, through industrial relocation or capital outflows, intensifies environmental issues in developing countries, yet simultaneously improves environmental quality through the introduction of green technologies and higher standards—thus the final environmental impact results from the interplay of these opposing effects [12]. Li Xiaoping et al. found no evidence of a “pollution haven” phenomenon between developed countries and China [13]. Jiang Xinying and Zhao Shuang reported that, with the exception of Beijing, Tianjin, and Shanghai, environmental regulations in other regions of China have increased the carbon emission intensity of FDI and worsened environmental pollution [14].

3. Research hypotheses

3.1. The mechanism of China's outward foreign direct investment (OFDI) impact on carbon emissions

The “pollution halo hypothesis” posits that multinational investment can improve host countries' environmental performance. Contrary to traditional perceptions, China, as an emerging investor in recent years, has demonstrated significant green characteristics in its OFDI under the Belt and Road Initiative (BRI). According to the Green Energy Cooperation Report jointly released by the China Energy Media Energy Security New Strategy Research Institute, the share of renewable energy investment in China's BRI projects increased by nearly 40% between 2014 and 2020. The core of this phenomenon lies in OFDI's suppressive impact on host countries' carbon emissions through channels such as technology spillovers, industrial restructuring, and energy consumption substitution. From a technological diffusion perspective, China's strategic investments in new energy and energy conservation/environmental protection have promoted low-carbon technological upgrades in host countries via the “reverse technology spillover” effect. For example, photovoltaic power station projects help reduce reliance on fossil fuels. From the standpoint of industrial linkages, OFDI drives the reshaping of global value chains. While China's investment in resource-intensive industries in developing countries may lead to increased pollution, its acquisitions of green R&D centers in developed countries can accelerate the reverse flow of clean technologies, resulting in a complex pattern of “carbon backflow” coexisting with pollution relocation. On the energy structure level, overseas investment in energy infrastructure demonstrates dual characteristics: on the one hand, projects involving traditional energy sources such as coal-fired power plants may increase regional carbon intensity; on the other hand, cooperation on renewable energy projects such as wind and hydropower supports the energy transition of host countries. The net effect of this mechanism depends on a triple interaction among the greenness of the investment structure, the stringency of host countries' environmental regulations, and the synergy of industrial upgrading in the home country. Therefore, a comprehensive analytical framework of “investment–technology–institution” must be established to deconstruct this mechanism.

Based on the above, this paper proposes:

Hypothesis 1: China's outward foreign direct investment has a significant suppressive effect on carbon emissions in Belt and Road Initiative countries.

3.2. Mechanisms of technological innovation and government effectiveness

The European Union's 2030 Climate and Energy Policy Framework emphasizes the crucial roles of technological innovation and capital in reducing greenhouse gas emissions. For BRI countries, foreign direct investment and multinational enterprises can introduce advanced environmental technologies and cleaner production methods, facilitating technology transfer, accelerating domestic industrial upgrading, and promoting more efficient, low-carbon modes of production. In addition, multinational investment may foster the establishment of joint ventures, R&D centers, and other platforms for international collaboration, advancing the research and application of carbon reduction technologies. With strong financial and technological foundations, foreign firms can contribute new products, production methods, and scientific business models, ultimately promoting the green and low-carbon development of local industries.

The government, undoubtedly, plays a vital role in achieving the "dual carbon" goals. A highly effective government can more precisely formulate and implement environmental policies and guide foreign investment toward green sectors. Conversely, countries with weak governance may struggle to effectively utilize the technologies brought by China's OFDI due to poor policy enforcement and low administrative efficiency, thereby undermining carbon reduction outcomes. Moreover, China's investment in BRI countries often involves cooperation with local governments, which plays a key role in improving institutional effectiveness. For instance, in the KK Highway project in Nepal, China Railway No. 2 Engineering Group, in cooperation with the local government and supervisory authorities, jointly released an environmental assessment report for construction and formulated several environmental regulatory documents. These actions indicate that China's BRI investment projects not only emphasize their own green development but also enhance the environmental governance capabilities of host governments through collaboration, thereby contributing to the suppression of carbon emissions.

Based on the above, the following hypotheses are proposed:

Hypothesis 2: In the process of outward foreign direct investment, China indirectly reduces carbon emissions in BRI countries by enhancing technological innovation capabilities.

Hypothesis 3: In the process of outward foreign direct investment, China indirectly reduces carbon emissions in BRI countries by leveraging the role of government effectiveness.

4. Selection of variables and model construction

4.1. Sample selection and data sources

This paper selects panel data from 2003 to 2023 for Belt and Road Initiative (BRI) countries. The data on China's direct investment in BRI countries comes from the annual China's Outward Foreign Direct Investment Statistical Bulletin, while other data are sourced from the World Development Indicators (WDI) database. Missing data are supplemented using linear interpolation.

4.2. Variable election

Dependent Variable: Carbon Emissions (pCO_2)

Per capita carbon dioxide emissions are chosen as the proxy variable for carbon emissions in BRI countries [15]. This indicator is calculated by dividing the total CO₂ emissions of a country by its total population.

Core Independent Variable and Control Variables: China's Outward Foreign Direct Investment Stock (OFDI)

China's OFDI mainly includes stock and flow data. Due to reverse investment behaviors in China, the flow data of OFDI often contain a large number of negative values. Therefore, this study uses the

stock of China's OFDI for analysis. To examine the impact of OFDI on carbon emissions, it is necessary to minimize the estimation errors caused by other unknown important variables. Based on practical considerations, the following control variables are included in the analysis: Economic Development Level (*pGDP*): There is a correlation between economic development and carbon emissions. The per capita GDP at constant 2015 prices for each BRI country is used as the measure [16]. Industrialization Level (*Ind*): Measured by the proportion of value added by the secondary industry in GDP. Population Density (*Pop*): Represented by the number of people per square kilometer. Urbanization Level (*Urban*): Represented by the proportion of the population living in urban areas. Information Dissemination (*Mob*): Measured by the number of mobile communication subscriptions per 1,000 people [17].

Mediator Variables: Technological Innovation (*Intech*) Represented by the number of scientific journal articles published [18]. Government Effectiveness (*Govern*) Measured by the World Bank's government effectiveness percentile ranking (where 0 indicates the lowest ranking and 100 indicates the highest ranking) [19].

4.3. Model construction

Based on data from 62 BRI countries between 2003 and 2023, this paper constructs an econometric model to explore the impact of China's OFDI on carbon emissions in BRI countries, excluding Bhutan, Palestine, Serbia, and Montenegro due to significant data gaps.

The empirical econometric model to investigate the impact of OFDI on carbon emissions is as follows:

$$pCO_{2it} = \beta_0 + \beta_1 OFDI_{it} + \beta_2 control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where i represents the country, t represents the year, β_0 is the intercept, and β_1 and β_2 are the corresponding estimated coefficients. μ_i represents the individual effects, δ_t represents the time effects, and ε_{it} represents the random disturbance term. pCO_{2it} represents the per capita carbon emissions of country i in year t , and $OFDI_{it}$ represents the scale of China's direct investment in country i in year t . $control_{it}$ is the set of control variables, including economic development level, industrial structure, and technological level, among other factors.

4.4. Descriptive statistics of variables

The descriptive statistics of each variable are shown in Table 1.

Table 1: Descriptive statistics of all variables

Indicator Category	Variable Name	Variable Symbol	Unit of Measurement	Sample Size	Mean	Standard Deviation	Maximum	Minimum
Dependent Variable	Per Capita Carbon Emissions	pCO_2	Ton per person	1,302	6.720	7.670	52.950	0.040
Independent Variable	Outward Foreign Direct Investment	$OFDI$	Billion USD	1,302	1.537	5.427	86.447	-0.048
	Economic Size	$pGDP$	Thousand USD	1,302	10.837	13.131	73.493	0.338
Control Variables	Degree of Industrialization	Ind	—	1,302	0.315	0.137	0.763	0.020
	Population Density	Pop	Thousand persons per square kilometer	1,302	6.935	2.272	12.246	-0.083
	Urbanization Level	$Urban$	—	1,302	0.582	0.214	1.000	0.145

Table 1: (continued).

	Information Dissemination	<i>Mob</i>	Units per thousand people	1,302	9.763	4.507	22.971	0.014
Mediating Variables	Technological Innovation	<i>Intech</i>	—	1,302	6.935	2.272	12.246	-0.083
	Government Effectiveness	<i>Govern</i>	—	1,302	48.389	24.962	100.000	0.000

5. Empirical results analysis

5.1. Baseline regression

This paper conducts an empirical test of the carbon emission effect of China's OFDI in the countries along the Belt and Road. The test results are shown in Table 2. ① There are three models available for panel data estimation: fixed effects model, random effects model, or mixed effects model. However, the fixed effects model can control for individual and time heterogeneity in the disturbance term, which could potentially lead to endogenous errors and improve the consistency of model estimates. Therefore, a two-way fixed effects model (both individual and time effects) is chosen. Additionally, the Hausman test statistic is 75.35, which rejects the null hypothesis at the 1% significance level, indicating that the fixed effects model should be selected. ② Column (1) in Table 2 shows the model without control variables, where China's OFDI is positively correlated with carbon emissions in the countries along the Belt and Road. However, after adding control variables in models (2) and (3), the coefficient of the core explanatory variable OFDI becomes significantly negative. This suggests that, after considering the economic development, industrial structure, population density, and information technology level of the countries along the Belt and Road, China's OFDI does not increase carbon emissions in these countries but rather has a significant inhibitory effect. A 1-unit increase in China's OFDI leads to a 0.024-unit decrease in per capita carbon emissions in these countries, thus confirming Hypothesis 1.

Table 2: Baseline regression results

Variable	<i>pCO₂</i>		
	(1)	(2)	(3)
<i>OFDI</i>	0.021** (2.27)	-0.018** (-1.97)	-0.024** (-2.54)
<i>Urban</i>		22.845*** (11.80)	22.285*** (11.59)
<i>pGDP</i>		0.163*** (9.91)	0.174*** (10.59)
<i>Ind</i>		1.746*** (2.69)	1.030 (1.57)
<i>Pop</i>			0.612* (1.88)
<i>Mob</i>			0.086*** (4.93)
<i>Constant</i>	6.676*** (42.71)	-7.994*** (-6.96)	-7.970*** (-6.98)
<i>Observations</i>	1,302	1,302	1,302
<i>R-squared</i>	0.023	0.163	0.182

Table 2: (continued).

<i>Control FE</i>	NO	YES	YES
<i>Country FE</i>	YES	YES	YES
<i>Year FE</i>	YES	YES	YES

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. The values in parentheses are the t-values.

In addition, some results within the control variables are also noteworthy. The coefficient of information dissemination is positive, contrary to expectations. The possible reason for this is that the green concept, due to the lack of supporting technologies, policies, and regulations, lags behind. As a result, even though the green concept has been widely popularized, it is still not effectively implemented in practice [20]. Therefore, the latest global greenhouse gas emissions statistics published by the World Bank show that the top ten Belt and Road countries in terms of emissions may still face challenges in technology transfer, leading to inefficient energy use and increased carbon emissions. At the same time, insufficient policy enforcement may also result in the failure of energy-saving and emission-reduction measures, making it an important factor contributing to the increase in carbon emissions. Consequently, the high carbon emissions in these countries may stem from low technology transfer efficiency and inadequate policy enforcement, rather than the direct impact of China's OFDI.

5.2. Robustness tests

5.2.1. Substituting the dependent variable

As one of the most energy-intensive sectors, the transportation industry is also a key focus in tackling climate change. The CO₂ emissions from energy used in transportation can directly reflect the carbon footprint of countries along the Belt and Road. Therefore, this study replaces per capita carbon emissions with transportation-related energy CO₂ emissions in Belt and Road countries for re-estimation [21]. As shown in column (1) of Table 3, the coefficient of the core explanatory variable remains significantly negative, indicating that the suppressive effect of China's OFDI on the carbon emissions of Belt and Road countries is robust.

5.2.2. Adding control variables

In the early stages of national development, public attention is primarily focused on meeting basic survival needs, with limited concern for low-carbon, environmentally friendly production methods. However, as the level of economic and social development improves, the conflict between economic growth and ecological protection becomes increasingly apparent, and public environmental awareness gradually strengthens, promoting the spread of green and sustainable development concepts. The shift from "survival first" to "ecology first" reflects the trajectory of societal advancement. In light of this, the level of social civilization development is incorporated into the regression framework. The social status of women has long been considered a key indicator of social progress; thus, this study uses the female labor force participation rate—defined as the percentage of women aged 15 and above participating in the labor force relative to the total female population—as a proxy for social civilization. The regression results, presented in column (2) of Table 3, show that the OFDI coefficient remains significantly negative, confirming the robustness of the baseline regression results.

5.2.3. Excluding abnormal years

During the COVID-19 pandemic, cross-border movement and transportation were severely restricted, significantly impeding global foreign direct investment. At the same time, industrial activities in many Belt and Road countries came to a standstill, temporarily affecting carbon emissions. Including pandemic years in the analysis could obscure the true relationship between OFDI and carbon emissions under normal economic conditions. To ensure the robustness of the findings, data from the pandemic years 2020 to 2022 are excluded. As shown in column (3) of Table 3, even after removing the impact of the pandemic, the coefficient for OFDI remains significantly negative.

Table 3: Robustness test results

Variable	<i>Intcarbon</i> (1)	<i>pCO2</i> (2)	(3)
<i>OFDI</i>	-0.004* (-1.87)	-0.019** (-2.04)	-0.028** (-2.55)
<i>Social</i>		-0.059*** (-4.69)	
<i>Constant</i>	0.598** (2.33)	-5.343*** (-4.23)	-7.908*** (-6.21)
<i>Observations</i>	1,302	1,302	1,116
<i>R-squared</i>	0.470	0.197	0.191
<i>Controls</i>	YES	YES	YES
<i>Country FE</i>	YES	YES	YES
<i>Year FE</i>	YES	YES	YES

5.2.4. Panel quantile regression

The baseline regression indicates that, overall, China's OFDI exerts a significant suppressive effect on carbon emissions in countries along the Belt and Road Initiative (BRI). However, traditional linear regression captures only the average relationship between variables and fails to account for the heterogeneity of the dependent variable across its distribution. Theoretically, countries with varying levels of carbon emissions differ significantly in terms of economic development and policy enforcement, which may lead to divergent impacts of China's OFDI. In light of this, we apply a quantile regression approach based on the distribution of per capita carbon emissions at different quantiles. Specifically, we estimate the regression coefficients at the 20th, 50th, 60th, 80th, and 90th percentiles to analyze the differentiated effects of OFDI on carbon emissions. As shown in the results in Table 4, the marginal effect of OFDI on carbon emissions is significantly negative across countries with different levels of carbon emissions, further confirming the robustness of the baseline results. To more intuitively present the influence of OFDI on countries at various emission levels, we conduct regression analyses at each quantile point from the 10th to the 90th percentile. After obtaining the marginal effects corresponding to each quantile, we plot the regression coefficients (see Figure 1). The results show that the suppressive effect of OFDI on carbon emissions is strongest around the 90th percentile and gradually weakens toward both ends of the distribution.

Countries at higher emission quantiles are mainly represented by Qatar, Kuwait, the United Arab Emirates, Bahrain, Oman, Saudi Arabia, and Russia. These nations or regions possess abundant oil and natural gas resources and are major global energy exporters. Their economies are heavily reliant on resource exports, with relatively homogenous industrial and energy structures and lagging technological development—though they still maintain considerable economic strength. As a result,

these countries generally exhibit strong capabilities and willingness to absorb green technologies, effectively localizing the clean production technologies brought by China's OFDI. By introducing China's advanced energy-saving and environmentally friendly technologies, these countries have significantly improved energy efficiency, accelerated the phase-out of outdated, energy-intensive production capacities, and promoted the green transformation of their production models. The more pronounced emission reduction effect observed at higher carbon emission levels further indicates that China's OFDI does not constitute a form of "pollution transfer."

Table 4: Panel quantile regression results

Variable	Q20	Q50	Q60	Q80	Q90
<i>OFDI</i>	-0.126*** (-9.11)	-0.198*** (-9.76)	-0.225*** (-9.41)	-0.234*** (-8.59)	-0.272*** (-5.39)
<i>Constant</i>	-2.438*** (-8.69)	-5.669*** (-13.74)	-5.222*** (-10.75)	-4.307*** (-7.78)	-3.834*** (-3.75)
<i>Observations</i>	1,302	1,302	1,302	1,302	1,302
<i>Controls</i>	YES	YES	YES	YES	YES

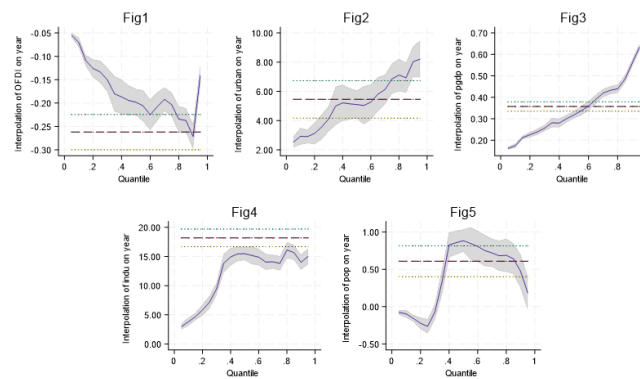


Figure 1: Quantile regression results

5.3. Endogeneity test

5.3.1. Instrumental variable approach

Countries that are partially dependent on fossil fuels may become less attractive for investment due to the global energy transition, while those leading in low-carbon technologies are more likely to attract China's green investment. At the same time, increasingly stringent environmental policies in various countries have raised the investment costs for high-carbon industries, which may deter China's OFDI. Given that carbon emission levels are closely related to countries' natural conditions and socioeconomic status, these levels may in turn influence how attractive countries are to Chinese investors, potentially leading to reverse causality. Therefore, the instrumental variable (IV) approach is adopted to address this potential endogeneity issue. Specifically, the logarithm of the number of international sister city relationships between China and each country is used as an instrumental variable for a two-stage least squares (2SLS) regression. Column (1) of Table 5 presents the first-stage regression results, where the coefficient of the instrumental variable $\ln IV$ is significantly positive at the 1% level, aligning with economic expectations. Furthermore, based on the Kleibergen-Paap rk LM statistic and the Cragg-Donald Wald F statistic, the null hypotheses of "under-identification" and "weak identification" are both rejected, indicating the instrumental variable is

valid and well-chosen. Column (2) of Table 5 shows the second-stage results, where the coefficient of OFDI is significantly negative at the 10% level. This suggests that, even after accounting for the potential reverse causality between OFDI and carbon emissions, Hypothesis 1 still holds.

5.3.2. Lagged explanatory variable

To mitigate the contemporaneous effects and thereby alleviate potential reverse causality, the lagged value of the explanatory variable is used in regression analysis. Specifically, China's OFDI is lagged by one period. As shown in Column (3) of Table 5, the regression coefficient of L.OFDI is -0.028 and significant at the 1% level, further confirming that the baseline regression remains robust after considering endogeneity.

Table 5: Endogeneity test results

Variable	(1)	(2)	(3)
	First Stage	Second Stage	Lagged One Period
	<i>OFDI</i>	<i>pCO2</i>	<i>pCO2</i>
<i>lnIV</i>	0.7975*** (2.714)		
<i>OFDI</i>		-0.7822* (-1.646)	
<i>L.OFDI</i>			-0.028*** (-2.77)
<i>Constant</i>	0.6015 (0.337)	-5.6374*** (-4.298)	-8.726*** (-7.37)
<i>Observations</i>	1,302	1,302	1,240
<i>R-squared</i>		0.673	0.203
<i>Controls</i>	YES	YES	YES
<i>Country FE</i>	YES	YES	YES
<i>Year FE</i>	YES	YES	YES
<i>Kleibergen-Paap</i>	5.088**		
<i>rk LM Statistic</i>	(0.024)		
<i>Cragg-Donald</i>	37.432		
<i>Wald F</i>	(12.56)		

5.4. Mechanism test

To avoid the endogeneity problem that may arise during the traditional “three-step method” for mechanism testing, this paper adopts a two-step approach following the research design of Jiang Ting [22]. In the hypothesis section, we have supported through literature review that promoting technological innovation and improving government effectiveness can influence carbon emissions in host countries. Equation (1) already verifies the effect of OFDI on carbon emissions. Therefore, it is sufficient to test whether OFDI has a significant impact on the mediating variables, which in turn validates the presence of mechanism effects. The mechanism model is set up as follows:

$$M_{it} = \beta_0 + \beta_1 OFDI_{it} + \beta_2 control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

In the equation, M_{it} represents the variable for either technological innovation or government effectiveness, while the remaining variables are defined as above.

By using Equations (1) and (2), the mechanism test is conducted. The results are presented in Table 6. In Column (2), the coefficient of OFDI is significantly positive at the 1% level, indicating that OFDI can significantly promote technological innovation, which in turn helps suppress carbon

emissions in host countries. After conducting a Bootstrap test (see Table 7), the 95% confidence interval does not include 0, demonstrating that technological innovation serves as a significant mediating factor. This suggests a transmission path of “OFDI → Technological Innovation → Carbon Emissions.”

In Column (3) of Table 6, the coefficient of OFDI is also significantly positive, suggesting that OFDI can enhance government effectiveness, thereby contributing to emission reduction in host countries. Similarly, the Bootstrap test confirms that the 95% confidence interval does not include 0. This indicates that improved government effectiveness is one of the key channels through which OFDI promotes carbon reduction, supporting Hypotheses 2 and 3.

Table 6: Two-Step mechanism test results

Variable	(1) <i>pCO2</i>	(2) <i>Intech</i>	(3) <i>Govern</i>
<i>OFDI</i>	-0.024** (-2.54)	0.012*** (3.76)	0.138** (2.47)
<i>Constant</i>	-7.970*** (-6.98)	4.412*** (11.14)	26.114*** (3.81)
<i>Observations</i>	1,302	1,302	1,302
<i>R-squared</i>	0.182	0.695	0.053
<i>Controls</i>	YES	YES	YES
<i>Country FE</i>	YES	YES	YES
<i>Year FE</i>	YES	YES	YES

Table 7: Bootstrap test results

Mediating Variable	Indirect/Direct Effect	Coefficient	Std. Error	p-value	95% Confidence Interval
<i>Intech</i>	Indirect Effect	-0.022	0.006	0.000	[-0.034, -0.010]
	Direct Effect	-0.240	0.021	0.000	[-0.280, -0.199]
<i>Govern</i>	Indirect Effect	0.010	0.004	0.008	[0.003, 0.017]
	Direct Effect	-0.272	0.019	0.000	[-0.310, -0.234]

5.5. Heterogeneity analysis

As demonstrated in the previous tests, China’s OFDI has an overall significant inhibitory effect on the carbon emissions of countries along the “Belt and Road” (B&R). Given the political, economic, and cultural diversity among these countries, does the impact of China’s OFDI on carbon emissions vary across them? This paper conducts a heterogeneity test using interaction terms ^[23].

5.5.1. OECD membership

OECD countries are committed to developing international norms that promote prosperity, equality, opportunity, and well-being. They actively support trade liberalization and facilitate cooperation among member states by offering data and analysis, experience-sharing, best practices, and platforms for public policy and global standard-setting. To further explore the impact of China’s OFDI on carbon emissions in countries with varying degrees of trade openness, a dummy variable *Isoecd* is introduced, which takes the value of 1 for OECD countries and 0 otherwise. The interaction term between *Isoecd* and the core explanatory variable is incorporated into the regression model to

compare the effect of China's OFDI on carbon emissions in OECD versus non-OECD countries. The regression results are reported in Column (1) of Table 8.

The regression results show that when $Isoecd=0$, the coefficient of China's OFDI on carbon emissions in non-OECD B&R countries is -0.026, which is significant at the 1% level. When $Isoecd=1$, the coefficient of China's OFDI on carbon emissions in OECD countries is -0.436, also significant. These results indicate that China's OFDI significantly reduces carbon emissions in B&R countries regardless of OECD membership. However, the carbon reduction effect is significantly stronger in OECD countries, reducing emissions by an additional 0.410 units compared to non-OECD countries.

This suggests that the inhibitory effect of OFDI on carbon emissions is associated with a country's level of trade openness. OECD members typically promote global trade and investment liberalization by reducing trade barriers and enhancing trade facilitation, which fosters international technology exchange and knowledge sharing. Consequently, Chinese investments in OECD countries are more likely to incorporate advanced environmental technologies, resulting in more effective carbon emission reductions.

5.5.2. Level of economic development

To further investigate the impact of China's OFDI on countries at different stages of economic development, a dummy variable $Isdeveloped$ is introduced, taking the value of 1 for developed countries and 0 otherwise. The results are presented in Column (2) of Table 8.

When $Isdeveloped=0$, the coefficient of OFDI is 0.033, which is not statistically significant. When $Isdeveloped=1$, the interaction term's coefficient is -0.070 and significant at the 1% level. This indicates that a one-unit increase in China's OFDI to a developed country leads to a 0.070-unit reduction in per capita carbon emissions. Therefore, the impact of China's OFDI on carbon emissions varies by the level of economic development, with significant carbon reduction effects in developed countries.

This finding suggests that the positive carbon mitigation effect of OFDI is closely related to a country's stage of economic development. Developed countries, with their advanced economies and technologies, possess well-established infrastructure, stricter environmental regulations, and mature financial systems. These factors enable Chinese OFDI to more effectively contribute to carbon reduction goals in such contexts.

5.5.3. Proximity to China

The B&R countries are geographically diverse, and the carbon reduction effect of China's OFDI may vary by location. This study categorizes B&R countries based on the geographic distance between their capitals and Beijing. A dummy variable $Isneighbor$ is introduced, which takes the value of 1 if the country shares a border with China and 0 otherwise. The results are shown in Column (3) of Table 8.

The regression results indicate that when $Isneighbor=0$, the OFDI coefficient is -0.175, significant at the 1% level. When $Isdeveloped=1$, the interaction term coefficient is 0.154, also significant at the 1% level. Possible explanations include: (1) Trade between China and its neighboring countries relies more on road and maritime transport, which tend to produce higher carbon emissions. In contrast, trade with non-neighboring countries increasingly utilizes low-carbon transportation modes such as China-Europe freight trains, thereby reducing emissions; (2) Many non-neighboring countries are developing or emerging economies (e.g., in Eastern Europe and Africa) with substantial potential for energy structure transformation, allowing Chinese green investment to significantly displace fossil fuel use. By contrast, some neighboring countries (e.g., Laos and Vietnam) are in a phase of rapid

industrialization and have high demand for energy-intensive industries such as coal and petroleum, limiting the environmental spillover effects of China's OFDI.

Table 8: Results of heterogeneity analysis

Variables	OECD Membership (1) pCO_2	Developed Country (2) pCO_2	Neighboring Country (3) pCO_2
<i>Isoecd*OFDI</i>	-0.436*** (-3.59)		
<i>Isdeveloped*OFDI</i>		-0.070*** (-3.04)	
<i>Isneighbor*OFDI</i>			0.154*** (2.73)
<i>OFDI</i>	-0.026*** (-2.81)	0.033 (1.58)	-0.175*** (-3.12)
<i>Constant</i>	-8.098*** (-7.12)	-6.921*** (-5.82)	-7.625*** (-6.65)
<i>Observations</i>	1,302	1,302	1,302
<i>R-squared</i>	0.191	0.188	0.187
<i>Controls</i>	YES	YES	YES
<i>Country FE</i>	YES	YES	YES
<i>Year FE</i>	YES	YES	YES

6. Research conclusions and policy recommendations

6.1. Research conclusions

First, China's outward foreign direct investment (OFDI) has significantly reduced carbon emissions in Belt and Road (B&R) countries, indicating that such investments are environmentally friendly and reflect a "pollution halo" effect, a conclusion that remains robust after a series of stability tests. Quantile regression further reveals that the effect of China's OFDI varies across countries with different levels of carbon emissions. Second, China's OFDI curbs carbon emissions in host countries through two main mechanisms: fostering technological innovation and enhancing government efficiency. Additionally, the impact of China's OFDI on carbon emissions differs significantly between OECD and non-OECD countries, with a more pronounced reduction effect observed in OECD countries. In terms of economic development, China's OFDI shows a significant emission reduction effect in developed countries, while its effect on developing countries warrants further investigation. Geographically, the emission reduction impact of China's OFDI also differs between neighboring and non-neighboring countries.

6.2. Policy recommendations

Based on these findings, the following policy recommendations are proposed:

First, as the initiator of the B&R Initiative, China should continue to uphold the new development philosophy of "innovation, coordination, greenness, openness, and sharing," actively engaging in low-carbon cooperative investment projects with B&R countries. Through OFDI, China should fully leverage the potential of low-carbon development to contribute to a green, mutually beneficial partnership with B&R countries and even the world.

Second, China should strengthen mechanisms for green technology sharing and improve government governance capacity. Joint technological collaboration with B&R countries should be

advanced, and talent in the field of renewable energy should be cultivated to establish globally recognized innovation hubs and talent centers in climate-related domains. When conducting overseas investments, China should closely cooperate with host governments to help improve environmental infrastructure and enhance environmental governance capabilities.

Third, China should adopt tailored investment strategies based on each B&R country's level of economic development, degree of trade openness, and geographic proximity, in order to maximize the positive environmental impacts of OFDI. Specifically: China could diversify investment methods in countries with high trade openness. These countries enjoy greater trade liberalization, which facilitates the exchange of green and clean technologies and helps aggregate the emission-reducing effects of OFDI. China should also support developing countries in improving their environmental standards so that the emission-reducing impact of OFDI can be effectively realized in both developing and developed nations, thereby jointly advancing global carbon reduction goals. Lastly, China could promote the construction of low-carbon transportation corridors to reduce carbon emissions from logistics in neighboring countries. This includes increasing the proportion of rail transport in trade with neighboring countries to reduce emissions from road transport. For non-neighboring countries, China should expand cooperation in clean technologies, promoting photovoltaic, wind, and related energy storage technologies in regions such as Africa and Eastern Europe, thereby facilitating energy transitions and collaborative green development.

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