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Green or Grey? The Carbon Emission Impacts of China's Outward Foreign Direct Investment: Mechanism and Heterogeneity Evidence

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Abstract

To empirically verify whether China's "Going-Out" strategy influences global carbon dioxide (CO₂) emissions, this study investigates the effect of China's outward foreign direct investment (OFDI) on recipient countries' CO₂ emissions, using a panel dataset of 68 countries over the period 2003–2021. In addition, we separately test the three major effects (i.e., scale, technical, and structure effects) of China's OFDI on recipient countries' CO₂ emissions. Considering the importance of the "Belt and Road Initiative" (B&RI) for China's "Going-Out" strategy, the global panel is divided into two subpanels (i.e., B&RI and non-B&RI countries) for empirical analysis. The results show that the total effect of China's OFDI on CO₂ emissions is positive for the global panel and B&RI countries but negative for the non-B&RI countries. Although China's OFDI increases recipient countries' CO₂ emissions by improving the economic scale (scale effect) and inhibiting the industrial upgrading (structure effect), the technical effect of China's OFDI alleviates the greenhouse effect. Based on the above findings, several targeted policy suggestions for mitigating recipient countries' CO₂ emissions and promoting growth in China's OFDI are provided.

Keywords: CO₂ emissions; China's "Going-Out" strategy; outward foreign direct investment; "Belt and Road Initiative" (B&RI) and non-B&RI countries; simultaneous equation model



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1. Introduction

Since the late 1990s, China has accelerated its integration into the global economic system by launching the "Going-Out" strategy, a pivotal national policy designed to encourage domestic enterprises to expand overseas investment and global business layout [1,2]. Driven by this strategic initiative, China's outward foreign direct investment (OFDI) has experienced explosive growth over the past two decades. Official statistics from the 2020 Statistical Bulletin of China's OFDI demonstrate a striking expansion in Chinese overseas investment entities, rising from merely 3400 in 2003 to 44,000 in 2019. In terms of investment stock, China's cumulative net OFDI surged by approximately 66-fold from \$33.2 billion US (constant 2010 US\$) in 2003 to \$2198.9 billion US in 2019, registering a

robust average annual growth rate of 28%. While the rapid expansion of cross-border investment has effectively boosted global economic cooperation and resource allocation, the environmental externalities of China's OFDI, particularly its implications for carbon dioxide (CO₂) emissions in recipient economies, have sparked growing scholarly and policy concerns [3,4]. As global carbon governance and low-carbon development gain unprecedented attention, recipient countries worldwide have gradually attached great importance to the environmental impacts brought by China's booming overseas investment. Nevertheless, extant research still lacks systematic and in-depth empirical analysis of the dynamic relationship between China's OFDI inflows and CO₂ emissions in recipient countries, leaving a critical research gap in relevant fields.

Complementing the "Going-Out" strategy, the Belt and Road Initiative (B&RI), proposed in 2013, has further unlocked new potential for China's overseas investment expansion and become a core driving force of its OFDI growth [5,6]. In the post-B&RI era, China's cumulative OFDI stock in B&RI countries has maintained sustained rapid growth, reaching \$179.5 billion in 2019 and accounting for 8.2% of China's total OFDI stocks. Notably, there exist substantial heterogeneous characteristics in China's investment layouts between B&RI and non-B&RI countries, which are largely overlooked in most prior studies. Specifically, China's OFDI in B&RI economies targets infrastructure construction, energy and power development, and cross-border mergers and acquisitions. Such investment projects are highly dependent on fossil energy consumption, inevitably generating substantial CO₂ emissions throughout their operational lifecycles [6–8]. In sharp contrast, China's overseas investment in non-B&RI countries is concentrated in low-carbon sectors including finance, technology, and cultural entertainment, resulting in relatively limited carbon emission externalities. Given this distinct sectoral and structural heterogeneity of China's OFDI across different recipient countries, it is theoretically and practically imperative to explore whether the carbon emission effects of China's OFDI vary significantly between B&RI and non-B&RI recipient countries. However, most of the existing literature on the OFDI-CO₂ nexus fails to distinguish between these two types of recipient economies, leading to one-sided research conclusions and insufficient targeted policy references.

Against this research backdrop and aiming to fill the above-mentioned gaps in the literature, this study systematically investigates the impact of China's OFDI on CO₂ emissions in recipient countries based on balanced panel data covering 68 economies from 2003 to 2021. Following the classical environmental effect decomposition framework, this research comprehensively identifies three core influential mechanisms of OFDI on CO₂ emissions, i.e., scale, technical, and structure effects. More importantly, to capture the heterogeneous impacts of investment heterogeneity, this study further divides the full sample into two sub-samples, B&RI and non-B&RI countries, and conducts grouped regression analysis to compare the differentiated carbon effects of China's OFDI. Accordingly, this study makes two major marginal contributions to the existing literature. First, it enriches the empirical evidence on the environmental consequences of international investment by quantitatively evaluating the dynamic linkage between China's large-scale overseas investment and global CO₂ emissions, providing a novel perspective for assessing the environmental implications of China's "Going-Out" strategy. Second, different from previous single-sample research, this study incorporates the structural heterogeneity of China's OFDI across B&RI and non-B&RI regions into the analytical framework, which clarifies the different emission mechanisms and effects in various recipient economies. The research findings can provide empirical support and targeted policy enlightenment for China to optimize its overseas investment structure, promote low-carbon B&RI construction, and participate in global carbon emission governance.

The remainder of this study is structured as follows: Section 2 reviews the existing literature, and Section 3 analyzes the theoretical mechanism. The methodology of this study is described in Section 4. Empirical results are provided in Section 5, and further discussion is presented in Section 6. Finally, Section 7 concludes the study and highlights policy implications.

2. Literature Review and Research Gaps

OFDI plays an increasingly important role in the process of globalization. Its environmental effects, especially the impact of CO₂ emissions, have become a research hotspot in the intersection of energy and environment. With the deepening implementation of China's "Going-Out" strategy and B&RI, the scale of China's OFDI has continued to expand, and attention is being drawn to the carbon effect it has triggered. Regarding the OFDI-CO₂ nexus, the academic community has formed two independent yet interwoven research paths: the impacts of OFDI on the CO₂ emissions of the home country and of the recipient country. Each of these two paths has accumulated rich research results, but there are significant differences in the core conclusions.

2.1. Review of the Carbon Effect of OFDI on CO₂ Emissions in the Home Country

The impact of OFDI on the home country's CO₂ emissions is the most widely discussed topic in the academic community. The core controversy lies in whether OFDI increases or reduces the CO₂ emissions of the home country. Current studies generally believe that OFDI affects CO₂ emissions through three main channels: scale, structure, and technological effects. Many studies, such as that by Hao et al. [9], support the conclusion that OFDI has a restraining effect on the CO₂ emissions of the home country. However, other studies have reached the opposite conclusion. Specifically, Yang et al. [10] conducted an empirical analysis using the panel data of 30 provinces in China from 2003 to 2017, and found that OFDI is positively correlated with the CO₂ emissions of the home country. The differences in the research conclusions indicate that the dynamic superposition of multiple effects may influence OFDI's impact. On the one hand, OFDI may transfer some high-carbon processes overseas, reducing the carbon intensity of domestic industrial production. On the other hand, the reverse technological spillover brought by overseas investment helps to enhance the domestic green technological level. The dominant position of each effect varies in different periods, regions, and industries, which constitutes an important theoretical depth in the research on the carbon emission effects of OFDI.

2.2. Review of the Carbon Effect of OFDI on CO₂ Emissions in the Recipient Country

The impact of OFDI on the CO₂ emissions of the recipient country is also highly controversial, giving rise to two opposing viewpoints: the pollution paradise and the pollution halo hypotheses. The former suggests that enterprises in pollution-intensive industries tend to locate in countries or regions with relatively low environmental standards. In contrast, the pollution halo hypothesis suggests that foreign investment leads to the saving of factors and resources by promoting environmentally friendly technologies in countries or regions, thus helping to improve environmental quality in the investing country [11–14]. Following these two hypotheses, many scholars empirically explore the potential environmental impacts of China's OFDI. For example, Xin and Zhang [15] tested the threshold effects of China's OFDI on environmental pollution based on a panel dataset involving China's 30 provinces covering the period of 2004–2015. Their research suggested that China's OFDI reduces sulfur dioxide (SO₂) and industrial wastewater in the provinces (see also [16]). While employing panel data of 29 Chinese provinces, Hao et al. [9] concluded that China's OFDI helped reduce domestic CO₂ emissions, where the alleviating effects

of the technical and industrial composition on pollution mitigate the positive scale effect. Furthermore, Luo et al. [3] found that China's OFDI was negatively associated with the greenhouse effect. However, Cai et al. [17] obtained the opposite conclusion, suggesting China's OFDI increased CO₂ emissions.

The above-discussed literature assesses the potential environmental impacts of China's OFDI on their emissions. A few studies focused on the effect of OFDI on the greenhouse effect in recipient countries. Among them, Ding et al. [18] analyzed the contribution of China's OFDI to carbon reduction in 43 recipient countries from 2000 to 2011. In addition, while focusing on China's OFDI in B&RI countries, Li et al. [19] showed that the technical and industry composition effects promoted carbon reduction, yet the scale effect was positive [20,21].

2.3. Literature Gaps

By comprehensively reviewing the existing research on the OFDI-CO₂ nexus both domestically and internationally, the current achievements have largely clarified the core theoretical mechanisms, basic transmission paths, and overall effect characteristics of OFDI on CO₂ emissions. However, there is still room for expansion in the existing research. Most studies employed fixed effects, mediation effects, and other econometric models for research. These models are mostly set up in a single equation, making it difficult to effectively address the multi-variable interdependent deviations between OFDI and the CO₂ emissions of the recipient country. Moreover, few studies used simultaneous equation models to systematically analyze their net effects. Although existing studies have paid attention to the heterogeneity in the national economy, environmental regulations, and investment motives, there is a scarcity of group comparison studies in B&RI and non-B&RI countries. This makes it difficult to meet the differentiated policy demands of green investment in the B&RI and global low-carbon governance.

3. Theoretical Mechanism Analysis

Only by accurately identifying the key factors among the complex economic and social factors that cause CO₂ emissions can government and industry formulate effective and targeted carbon reduction policies. Therefore, to explore the influencing mechanism of China's OFDI on the recipient countries' CO₂ emissions, this study expands the model framework proposed in [22] and separates CO₂ emissions into three effects (i.e., scale, technical, and structure effects) from the perspective of production.

Specifically, we assume that an economy employs labor (denoted as L) and capital (denoted as K) to produce two final products (i.e., X and Y), which are polluted products and clean products, respectively. Additionally, the production function $F(K, L)$ satisfies the assumption that the return to scale is constant, and the representative manufacturers produce CO₂ in the process of producing X , which imposes negative externalities on economic units. When pollution rights are clearly defined and trading costs are low, firms must pay a marginal cost λ for CO₂ emissions, which is assumed to be constant.

In addition, to maximize profits, polluters use part of their production factors to reduce CO₂ emissions, and thus, the ratio of the resources that the polluters used to the potential output F is denoted as $\gamma \in [0, 1]$. Notably, $\gamma = 0$ means that the manufacturer does not control CO₂ emissions at all, and $0 < \gamma < 1$ indicates that CO₂ emissions take up resources that will be used to produce economic output in the future. In this case, the actual output of the manufacturer is $X = (1 - \gamma)F(K_X, L_X)$, and the actual CO₂ emissions can be set as $CO_2 = \phi(\gamma) \times F(K_X, L_X)$, where $\phi(\gamma)$ represents the CO₂ emissions function, which is the minus function of γ ; its specific form is set as $\phi(\gamma) = A^{-1}(1 - \gamma)^{1/a}$, where A indicates

technical progress and $\alpha \in (0, 1)$. Therefore, $CO_2 = A^{-1}(1 - \gamma)^{1/a} F(K_X, L_X)$. According to the above analysis, the production function of polluting product X is as follows:

$$X = (A \times CO_2)^a [F(K, L)]^{1-a} \quad (1)$$

where a is the proportion of pollution factor input in the total cost. The production of polluting product X requires two inputs: effective polluting emissions ($A \times CO_2$) and potential output (F).

Following Equation (1), the decision-making process of profit maximization in the production of polluting product X can be divided into two stages:

- (1) Given the capital price (r) and labor price (w), the optimal allocation combination of capital and labor must be chosen so that the cost per unit of potential output is the lowest.
- (2) Given the marginal cost of pollution emissions (λ) and the per-unit potential output cost (C^F), the optimal configuration combination of CO_2 emissions and potential output (F) must be chosen to ensure that the production cost of per-unit pollution product X is the lowest. Therefore, the cost minimization problem can be expressed as follows:

$$C^F(\bar{K}, \bar{L}) = \min\{r\bar{K} + w\bar{L}, F(\bar{K}, \bar{L}) = 1\} \quad (2)$$

$$C^X(CO_2, F) = \min\{\lambda(A \times CO_2) + C^F F, (A \times CO_2)^a F^{1-a} = 1\} \quad (3)$$

By solving the first-order conditions for Equations (2) and (3), respectively, we obtain

$$\frac{\partial F}{\partial K} / \frac{\partial F}{\partial L} = \frac{r}{w} \quad (4)$$

$$\frac{(1-a)A \times CO_2}{aF} = \frac{C^F}{\lambda} \quad (5)$$

where both Equations (4) and (5) indicate that the ratio of marginal output of the two factors is equal to the relative price of the two factors according to the profit maximization condition.

Next, we must further investigate the optimal pollution emissions decision. We assume that the price of the polluting product is P^X , so the total revenue is $TR = P^X X$, the total cost is $TC = C^F F + \lambda(A \times CO_2)$, and the profit function is $\pi = TR - TC$. In a perfectly competitive market, the manufacturer's net profit in the long-term equilibrium is 0, so we obtain

$$P^X X = C^F F + \lambda(A \times CO_2) \quad (6)$$

By substituting Equation (6) into Equation (5), the intensity of CO_2 emissions can be obtained:

$$\frac{CO_2}{X} = \frac{\alpha P^X}{\lambda A} \quad (7)$$

Equation (7) indicates that the manufacturer's optimal intensity of CO_2 emissions is negatively correlated with technical progress (A) and positively correlated with the price of polluting products (P^X).

Equation (7) can also be converted to

$$CO_2 = (P^X X + P^Y Y) \cdot \frac{\alpha}{\lambda A} \cdot \frac{P^X X}{P^X X + P^Y Y} \quad (8)$$

Assume the price of a clean product is P^Y , and define the following:

- The total output of the economy is $Scale = P^X X + P^Y Y$ (i.e., scale effect);
- Technological progress is $Tech = \alpha / \lambda A$ (i.e., technical effect);

- The proportion of output value of polluting products in the total output value is $Stru = P^X X / (P^X X + P^Y Y)$ (i.e., structure effect).

Therefore, Equation (8) can be converted as follows:

$$CO_2 = Scale \times Stru \times Tech \quad (9)$$

According to Equation (9), CO₂ emissions mainly depend on three factors: economic scale (*Scale*), industrial structure (*Stru*), and technological level (*Tech*). The theoretical mechanism is basically consistent with Hao et al. [9]. Therefore, based on the literature review and China's reality, the impact mechanism of China's OFDI on recipient countries' CO₂ emissions can be summarized in three aspects.

3.1. Mechanism I: Scale Effect

The scale effect of OFDI on the recipient countries' CO₂ emissions insists that if the recipient countries introduce foreign capital, the economic scale will expand, thus increasing CO₂ emissions [23,24]. Specifically, different enterprises have incentives when investing, mainly including resource-, market-, and technology-seeking. Also, profit-seeking investments play a critical role in the long-run growth process [25]. Obviously, investment will increase the level of economic development and boost the recipient countries' development funds [9]. However, expanding the economic scale will lead to expansion of the production scale, which will consume petrochemical energy, thereby leading to environmental deterioration and increasing CO₂ emissions.

Additionally, according to the environmental Kuznets curve (EKC) proposed in Grossman and Krueger [26], both the economic development and environmental quality, including CO₂ emissions, have a significant inverted U-shaped feature; this is also supported by Alam et al. [27], Bilgili et al. [28], Guo and Shahbaz [29], Kang et al. [30], Li et al. [31], and Nasir and Rehman [32]. The reason for the inverted U-shaped curve is that economic growth leads to the improvement of basic economic functions, which leads to residents having improved awareness of environmental protection, upgrading of industrial structure, and progress in green technology [33]. As a result, controlling for other factors makes it difficult to reduce CO₂ emissions as the economy grows. In other words, if China's OFDI promotes the recipient countries' economic growth, its scale effect will exacerbate the recipient countries' CO₂ emissions; thus, the first hypothesis is proposed:

H1. *China's OFDI increases the recipient countries' CO₂ emissions through the scale effect.*

3.2. Mechanism II: Technical Effect

The technical effect of OFDI refers to the simultaneous introduction of foreign capital and advanced environmental protection and low-carbon technologies, which creates a spillover effect on the reduction in CO₂ emissions [14,23,34]. Through OFDI, on the one hand, the recipient countries strengthen cooperation and transnational communication of low-carbon technologies [35–37]. On the other hand, the recipient countries experience improved economic development, and the demand for a high-quality environment begins to grow, which may result in the introduction of cleaner technologies and thus a reduction in CO₂ emissions [34]. To date, only a few studies have tested the technology spillover effect of OFDI [38,39], indicating that only recipient countries with relatively higher research and development (R&D) input can increase their domestic productivity [40]. Therefore, this study proposes the second hypothesis:

H2. *China's OFDI can reduce CO₂ emissions through technical change.*

3.3. Mechanism III: Structure Effect

The structure effect of OFDI indicates the interrelationship between industrial structure and environmental pollution, namely, the environmental influence arising from the transformation of industrial structure [41,42]. Specifically, when a country's leading industry is pollution-intensive, it increases environmental pollution, whereas when a country's industrial structure is dominated by clean-intensive industries, the impact of environmental pollution is small [43]. To the best of our knowledge, the secondary industry is dominated by resource-intensive and pollution-intensive sectors, which are likely to produce more CO₂ emissions. Conversely, the tertiary industry is characterized as being knowledge- and technology-intensive and thus produces less pollution. The recipient countries achieve good environmental performance by promoting industrial transfer, mainly including two aspects (i.e., industrial structure rationalization and industrial structure advancement), which is beneficial for mitigating CO₂ emissions [4,44–46]. Thus, the third hypothesis is as follows:

H3. *China's OFDI alleviates the recipient countries' CO₂ emissions through industrial composition.*

In summary, the impact of China's OFDI on recipient countries' CO₂ emissions includes at least the economic scale, industrial structure, and technological progress; the influencing mechanism is depicted in Figure 1.

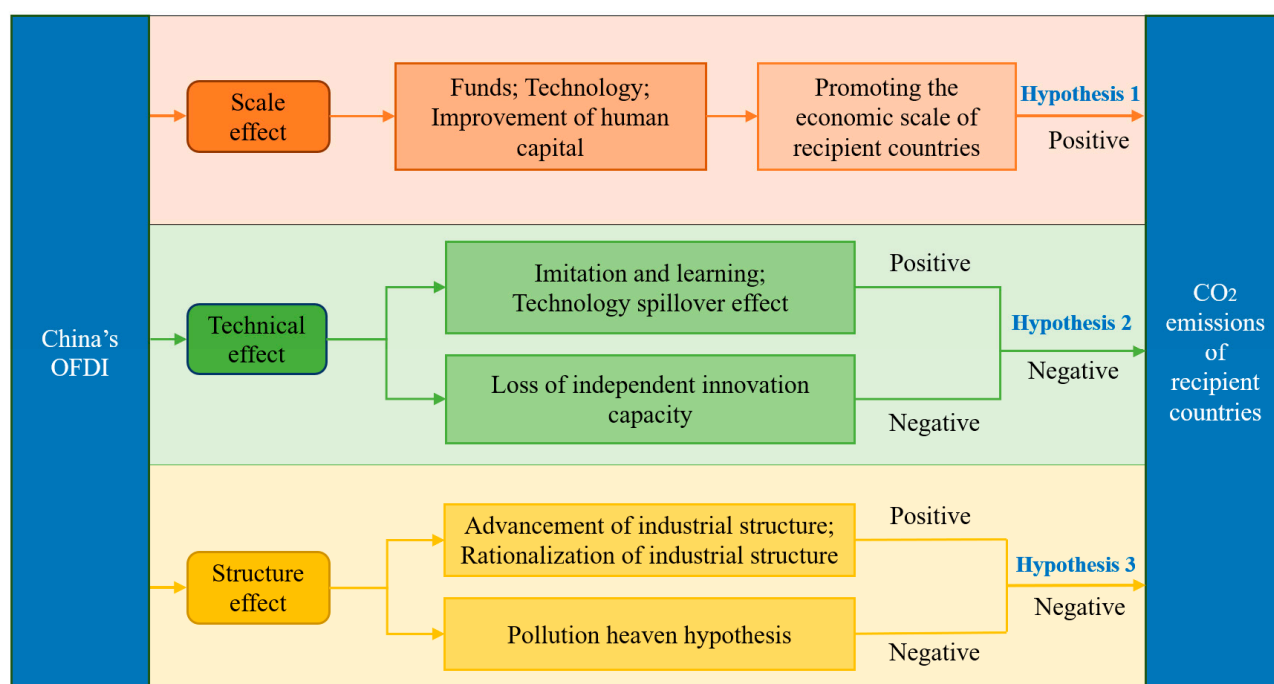


Figure 1. Impact mechanism of OFDI on CO₂ emissions in recipient countries.

4. Methodology

4.1. Econometric Models

Based on the theoretical mechanism, we divide the effect of China's OFDI on the recipient countries' CO₂ emissions into three aspects: scale, technical, and structure effects. Adding the logarithm to both sides of Equation (9) yields

$$\ln CO_2 = \ln Scale + \ln Tech + \ln Stru \quad (10)$$

Equation (10) implies that changes in China's OFDI will give rise to the three effects, which will eventually influence the recipient countries' CO₂ emissions. Therefore, we

select the simultaneous equation model for empirical analysis; the model can be expressed as follows:

$$\ln CO_{2it} = \varphi_1 \ln Scale_{it} + \varphi_2 \ln Tech_{it} + \varphi_3 \ln Stru_{it} + \varepsilon_{it} \quad (11)$$

$$\ln Scale_{it} = \alpha_0 + \alpha_1 \ln OFDI_{it} + \alpha_2 \ln Tra_{it} + \alpha_3 \ln Urb_{it} + \alpha_4 \ln Den_{it} + \varepsilon_{it} \quad (12)$$

$$\ln Tech_{it} = \beta_0 + \beta_1 \ln OFDI_{it} + \beta_2 \ln Tra_{it} + \beta_3 \ln Urb_{it} + \beta_4 \ln Pgdp_{it} + \varepsilon_{it} \quad (13)$$

$$\ln Stru_{it} = \delta_0 + \delta_1 \ln OFDI_{it} + \delta_2 \ln Tra_{it} + \delta_3 \ln Urb_{it} + \delta_4 \ln Pgdp_{it} + \delta_5 \ln Lab_{it} + \varepsilon_{it} \quad (14)$$

where i and t denote country and year, respectively, and ε represents the random error term. Also, Equation (11) indicates the total effect of the equation. Equations (12)–(14) represent the scale, technical, and structure effects brought by China's OFDI change, respectively. Notably, the actual net impact of China's OFDI on CO₂ is not directly represented by a single coefficient. Instead, it is transmitted through three indirect paths—scale, technology, and structure—and is the sum of these effects. By substituting Equations (12)–(14) into Equation (11) and taking the partial derivative of the core variable $\ln OFDI$, we obtain the total marginal elasticity (i.e., net effect) of OFDI on CO₂ emissions:

$$\partial \ln CO_2 / \partial \ln OFDI = \varphi_1 \alpha_1 + \varphi_2 \beta_1 + \varphi_3 \delta_1 \quad (15)$$

This net effect can be separated into the following three pathways:

1. Scale effect ($\varphi_1 \alpha_1$): China's OFDI affects economic scale, which affects CO₂ emissions. If $\varphi_1 \alpha_1$ is greater than 0, this path leads to an increase in CO₂ emissions and a reduction in CO₂.
2. Technical effect ($\varphi_2 \beta_1$): China's OFDI affects technological level, which affects CO₂ emissions. If the value is greater than 0, this path leads to an increase in emissions and a reduction in CO₂.
3. Structural effect ($\varphi_3 \delta_1$): China's OFDI affects the industrial structure, which affects CO₂ emissions. If $\varphi_3 \delta_1$ is greater than 0, this path leads to an increase in emissions and a reduction in emissions.

4.2. Variables and Data

A balanced panel of data covering 68 global countries from 2003 to 2021 was utilized in this study, yielding a total of 1292 observations. Notably, we chose 68 countries mainly due to the limitations of carbon emission data. The data for CO₂ emissions (denoted as CO₂) were obtained from the former British Petroleum (BP) Statistical Review of World Energy; to ensure consistency in data sources, we selected 68 countries included in this database. The data for China's OFDI are from the Statistical Bulletin of China's OFDI.

The scale effect (*Scale*) is measured by the gross domestic product (GDP) of each recipient country [47], the technical effect (*Tech*) is measured by the ratio of the GDP to energy consumption (i.e., energy efficiency) of each recipient country [48,49], and the structure effect (*Stru*) is measured by the proportion of the secondary industry in GDP [50].

Furthermore, we also selected five control variables (i.e., economic development, trade openness, population density, employment, and urbanization evolution). These five dimensions cover the core macro factors that affect the CO₂ emissions of each recipient country, and they are in line with the EKC theory and the three major environmental effect theories, effectively avoiding the problem of omitted variables. Moreover, all variables are highly correlated with the location selection and investment structure of China's OFDI and can precisely separate various interfering factors, ensuring the estimation accuracy of the simultaneous equation model to the greatest extent. The measures of the five control variables are as follows: economic development (*Pgdp*) is measured by per capita GDP in constant 2010 US\$, trade openness (*Tra*) by the ratio of total import and export

trade to GDP [51], population density (*Den*) by the population per square kilometer [52], employment (*Lab*) by the number of employees in each country [53], and urbanization evolution (*Urb*) by the proportion of the urban population in each country's total population. The data for the above variables were obtained from the World Bank. The descriptive statistics of the variables are listed in Table 1. Tables A1 and A2 in Appendix A present the multicollinearity test and cross-sectional dependence test, respectively.

Table 1. Descriptive statistics of the variables (after logarithm).

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
lnCO ₂	1292	4.79414	1.328128	1.94591	8.680026
lnOFDI	1292	10.00644	2.83204	0.00000	15.89555
lnScale	1292	26.37075	1.375149	23.13596	30.65288
lnTech	1292	7.121208	0.6771578	5.030127	8.87342
lnStru	1292	0.8017998	0.5597358	−1.227556	2.179537
lnPgdp	1292	9.458452	1.163686	6.549268	11.62998
lnLab	1292	16.14296	1.425386	12.19944	20.04541
lnDen	1292	4.374788	1.354867	0.9427517	8.982923
lnTra	1292	4.319693	0.5454783	3.059933	6.080681
lnUrb	1292	4.194227	0.3123971	2.901202	4.60517

5. Results and Discussions

5.1. Benchmark Estimates

We depict the outcomes of the three-stage least squares (3SLS) regression in Table 2. The 3SLS model mainly determines the presence of weak instrumental variable issues based on the value of the F-statistic in the first stage. In this table, the F-statistics are all greater than 10, indicating that there is no weak instrumental variable problem. Using this method to test the OFDI-CO₂ nexus is feasible.

Regarding the scale effect, we note a significant positive correlation between China's OFDI and economic scale. This implies that China's OFDI promotes economic development in the recipient countries, which is consistent with the conclusion of Zhu et al. [54]. A 1% increase in China's OFDI causes recipient countries' economic activity to increase by approximately 0.100%, contributing to their economic growth. Furthermore, the coefficient of the lnScale in the first column is 1.191, which is significantly positive at the 1% level. This indicates that an increase in economic scale will significantly increase CO₂ emissions. It also suggests that China's OFDI will significantly promote CO₂ emissions by expanding the recipient countries' economic scale, which supports H₁. In addition, population density, urbanization evolution, and labor force positively impact the economic scale. Specifically, a 1% increase in population density is associated with a 0.084% increase in economic scale. In comparison, a 1% increase in urbanization evolution leads to a 1.515% increase in economic scale, and a 1% increase in labor force leads to a 0.700% increase in economic scale. Finally, trade openness, reflecting the frequent trade exchanges between countries, shows an insignificant positive correlation with economic scale. The use of a negative sign indicates that China's OFDI generally possesses a potential mechanism to stimulate the economic growth of the recipient country. For instance, it can fill the savings gap of the recipient country through capital flows, expand production and employment, or leverage infrastructure and manufacturing investments to drive the development of the local upstream and downstream industrial chains, thereby creating positive growth transmission. However, multiple constraints such as the time lag effect of OFDI, the absorption capacity of the recipient country, and the structure and quality of China's OFDI may jointly dilute the growth benefits of the OFDI.

The analysis also suggests that China's OFDI has a positive technical effect. Specifically, a 1% increase in China's OFDI yields a 0.009% increase in energy efficiency. Furthermore, our analysis implies a negative correlation between energy efficiency and CO₂ emissions. Thus, China's OFDI effect on global CO₂ emissions is negative. We can thus accept H₂ because, on the one hand, China's OFDI can optimize and make up for the original equipment and facilities by providing abundant capital and advanced technology to recipient countries, breaking through the initial development bottlenecks and innovation obstacles. On the other hand, when conducting foreign investment, Chinese companies will directly set up local R&D institutions to promote local independent R&D or cooperative R&D activities and increase the R&D capacity of local companies through technology diffusion and dissemination effects, promoting green technological innovation. In addition, economic growth is positively associated with improved energy efficiency, while rapid urbanization evolution negatively affects energy efficiency by causing a significant increase in large-scale infrastructure construction, residential energy consumption, and transportation energy consumption. Under extensive construction, the energy-saving supporting facilities lag behind, thereby lowering the overall energy utilization efficiency.

Table 2. Benchmark regression results.

Dep. Var.	Carbon Effect	Scale Effect	Technical Effect	Structural Effect
	(1)	(2)	(3)	(4)
	lnCO ₂	lnScale	lnTech	lnStru
lnOFDI		0.100 *** (9.87)	0.009 *** (3.63)	−0.013 *** (−3.97)
lnUrb		1.515 *** (21.77)	−1.591 *** (−18.63)	0.260 ** (2.15)
lnTra		0.056 (1.13)		−0.432 *** (−16.67)
lnLab		0.700 *** (34.27)		−0.108 ** (−2.43)
lnPgdp			0.445 *** (19.46)	−0.531 *** (15.66)
lnDen		0.084 *** (5.61)		
lnScale	1.191 *** (106.69)			
lnTech	−1.065 *** (−48.52)			
lnStru	0.046 ** (2.25)			
_Cons	−18.729 *** (−61.12)	6.981 *** (13.27)	9.561 *** (26.44)	−1.270 *** (−3.17)
Region fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
F test	2497.99	99,999.00	930.33	285.59
p-value	0.0000	0.0000	0.0000	0.0000
Obs.	1292	1292	1292	1292

Notes: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. The values in parentheses are z-values.

China's OFDI is negatively related to the structure effect; a 1% increase in China's OFDI causes a drop of −0.013% in industrial structure upgrading. The total effect shows that industrial upgrading can significantly increase CO₂ emissions, which is in contrast to the findings of Hao et al. [9], Liu et al. [20], and Tian et al. [55]. This suggests that China's OFDI will increase CO₂ emissions by increasing the proportion of the secondary industry

and reducing that of the tertiary industry, which contradicts our expected assumption. Thus, we reject H₃. Li and Luo [56] indicated that in the past, countries tended to invest in the secondary industry, which might yield more profits than investing in the tertiary industry. In May 2017, guiding opinions on promoting green B&RI further explained the significance of constructing green B&RI, and companies have gradually learned about the importance of sustainable development, resulting in the less polluting tertiary industry becoming more attractive to investors than the manufacturing industry [57,58]. However, although China began to flow to the tertiary sector, secondary sectors such as mining and manufacturing still account for a high proportion, especially in B&RI countries. In addition, the transformation from labor-intensive to capital-intensive industries is a long process. Accordingly, when Chinese companies invest abroad, it is necessary to gradually adjust the investment structure to help recipient countries achieve carbon emission targets.

In summary, we calculated the total marginal elasticity of OFDI on CO₂ emissions using Equation (15): $0.100 \times 1.191 + 0.009 \times (-1.065) + (-0.013) \times 0.046 = 0.108917 > 0$. This indicates that the net impact of China's OFDI on the CO₂ emissions of the recipient country is significantly positive, suggesting an adverse impact.

5.2. Robust Checks

5.2.1. Estimation Using the Single Equation Method

We employed a single equation instrumental variable estimation method (i.e., two-stage least squares (2SLS)), and the results are shown in Table 3. During this process, we used the lagged value of the independent variable as the instrumental variable and conducted the underidentification test and weak identification test. The corresponding values (i.e., K-P rk LM statistic and K-P rk Wald F statistic) are reported in Table 3. The results show that the instrumental variables are reliable, and $1.192 \times 0.319 + (-1.066) \times 0.011 + 0.027 \times (-0.015) = 0.368117 > 0$. The benchmark regression results indicating the positive relationship between China's OFDI and CO₂ emissions are robust.

Table 3. Robust results after using the single equation method.

Dep. Var.	Carbon Effect	Scale Effect	Technical Effect	Structural Effect
	(1)	(2)	(3)	(4)
	lnCO ₂	lnScale	lnTech	lnStru
lnOFDI		0.319 *** (24.91)	0.011 *** (2.75)	−0.015 *** (−2.76)
Control variables	Yes	Yes	Yes	Yes
lnScale	1.192 *** (90.88)			
lnTech	−1.066 *** (−70.78)			
lnStru	0.027 *** (3.16)			
_Cons	−18.768 *** (−57.39)	6.981 *** (13.27)	9.749 *** (19.64)	5.524 *** (4.42)
Region fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
K-P rk LM statistic	261.892 [0.0000]	422.870 [0.0000]	160.616 [0.0000]	164.195 [0.0000]
K-P rk Wald F statistic	4849.081 {16.38}	4560.209 {16.38}	372.217 {16.38}	379.685 {16.38}
R ²	0.9990	0.6142	0.9861	0.9579
Obs.	1224	1224	1224	1224

Notes: *** indicates statistical significance at the 1% level. The values in parentheses are z-values, those in brackets are p-values, and those in braces are critical values from the Stock–Yogo weak ID test.

5.2.2. Estimation Using the Alternative Independent Variables

To check the reliability of our estimation results, we used an alternative definition for our independent variable: China's OFDI measured by the absolute value of the flows of China's OFDI (*OFDI_L*) and China's per capita OFDI (i.e., the proportion of China's total OFDI and total population; *OFDI_P*), respectively. The results are displayed in the left and right four columns of Table 4, respectively. The calculation revealed that the net impact of China's OFDI on CO₂ emissions is significantly positive in all cases, which proves the accuracy and reliability of the baseline regression results.

Table 4. Robust results after applying alternative independent variables.

Dep. Var.	OFDI Flows				Per Capita OFDI			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnCO ₂	lnScale	lnTech	lnStru	lnCO ₂	lnScale	lnTech	lnStru
lnOFDI_L		0.048 *** (7.28)	0.005 *** (4.06)	−0.003 * (−1.95)				
lnOFDI_P						0.107 *** (10.63)	0.010 *** (4.25)	−0.014 *** (−4.03)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
lnScale	1.191 *** (106.54)				1.191 *** (106.69)			
lnTech	−1.068 *** (−48.87)				−1.065 *** (−48.51)			
lnStru	0.047 ** (2.23)				0.046 ** (2.25)			
_Cons	−18.723 *** (−61.06)	6.277 *** (11.93)	0.598 *** (26.66)	6.747 *** (7.63)	−18.729 *** (−61.12)	7.374 *** (13.84)	9.710 *** (27.06)	6.584 *** (7.48)
Region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test	2501.16	99,999.00	929.85	282.79	2497.94	99,999.00	930.30	285.59
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Obs.	1292	1292	1292	1292	1292	1292	1292	1292

Notes: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The values in parentheses are z-values.

5.2.3. Estimation Using the Alternative Dependent Variable

We further applied the carbon emission intensity (i.e., the amount of CO₂ emissions per unit of GDP; *COG*) as the dependent variable and employed the 3SLS and 2SLS methods for regression analysis simultaneously; the results are presented in Table 5. By calculating the overall effect of China's OFDI on carbon emission intensity, we can observe that China's OFDI will increase the carbon intensity of the recipient country, which is consistent with the results of the baseline regression.

Table 5. Robust results of applying alternative dependent variable.

Dep. Var.	3SLS Estimation				2SLS Estimation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnCOG	lnScale	lnTech	lnStru	lnCOG	lnScale	lnTech	lnStru
lnOFDI		0.100 *** (9.87)	0.009 *** (0.002)	−0.013 *** (−3.97)		0.319 *** (24.91)	0.011 *** (2.75)	−0.015 *** (−2.76)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
lnScale	0.191 *** (17.11)				0.192 *** (14.65)			
lnTech	−1.065 *** (−48.56)				−1.067 *** (−70.60)			
lnStru	0.046 ** (2.25)				0.027 *** (3.15)			

Table 5. Cont.

Dep. Var.	3SLS Estimation				2SLS Estimation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnCOG	lnScale	lnTech	lnStru	lnCOG	lnScale	lnTech	lnStru
_Cons	−18.729 *** (−61.17)	6.981 *** (13.27)	9.561 *** (26.44)	6.686 *** (7.60)	−18.768 *** (−57.34)	6.981 *** (13.27)	9.749 *** (19.64)	5.524 *** (4.42)
Region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K-P rk LM statistic					261.892 [0.0000]	422.870 [0.0000]	160.616 [0.0000]	164.195 [0.0000]
K-P rk Wald F statistic					4849.081 {16.38}	4560.209 {16.38}	372.217 {16.38}	379.685 {16.38}
F test	819.44	99,999.00	930.33	285.59				
p-value	0.0000	0.0000	0.0000	0.0000				
Obs.	1292	1292	1292	1292	1224	1224	1224	1224

Notes: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. The values in parentheses are z-values, those in brackets are p-values, and those in braces are critical values of the Stock–Yogo weak ID test.

5.2.4. Excluding the Financial Crisis in 2008 and the COVID-19 Pandemic in 2020

Major exogenous shocks simultaneously disturb the two core variables of China's OFDI flow and the CO₂ emissions of each recipient country, resulting in abnormal values in the sample and short-term deviations from the baseline regression. To eliminate the interference of major sudden exogenous shocks on the regression results, we excluded the observation samples of 2008, the year of the global financial crisis, and 2020 and 2021, during the COVID-19 outbreak; the results are shown in Table 6. After excluding the special shock years, the sign and significance of the coefficient of the core variables did not change substantially, and after calculation, we found that the net effect of China's OFDI on the CO₂ emissions of the recipient country is still positive, proving that the baseline regression conclusion is not disturbed by extreme macro shocks and the research conclusion is robust and reliable.

Table 6. Robust results after excluding special values and using lagged terms for the independent variable.

Dep. Var.	Excluding Special Values				Using Lagged Terms of Independent Variable			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnCO ₂	lnScale	lnTech	lnStru	lnCO ₂	lnScale	lnTech	lnStru
lnOFDI		0.094 *** (8.59)	0.006 ** (2.45)	−0.013 *** (−3.84)				
L.lnOFDI						0.097 *** (9.38)	0.008 *** (3.50)	−0.011 *** (−3.41)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
lnScale	1.165 *** (96.11)				1.190 *** (101.22)			
lnTech	−1.049 *** (−47.40)				−1.047 *** (−42.09)			
lnStru	0.024 (1.13)				0.054 ** (2.48)			
_Cons	−18.190 *** (−56.52)	6.743 *** (11.69)	9.295 *** (22.89)	7.682 *** (8.03)	−18.825 *** (−55.96)	6.944 *** (12.91)	9.829 *** (26.15)	6.143 *** (6.60)
Region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test	2414.67	99,999.00	868.21	268.64	2632.05	99,999.00	977.47	287.14
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Obs.	1088	1088	1088	1088	1224	1224	1224	1224

Notes: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. The values in parentheses are z-values.

5.2.5. Using the Lagged Terms of the Independent Variable

Notably, the econometric model may be subject to potential endogeneity arising from bidirectional causality. On the one hand, the host country's contemporaneous carbon emission level may reversely affect the current location choice of Chinese enterprises' investment, thereby introducing bias into the baseline regression estimates. However, the lagged term of the OFDI variable is determined solely by the economic and policy conditions of the previous period and cannot be reversely influenced by current CO₂ emissions, thus effectively mitigating endogeneity concerns. On the other hand, given the construction cycles inherent in Chinese overseas greenfield investments, infrastructure, and industrial projects, the effects of investment inflows on the recipient country's energy consumption, industrial structure, and CO₂ emissions are unlikely to be fully materialized within the current period; therefore, the lagged variable better captures the true transmission path.

To accommodate the objective reality of time lags in the impact of China's OFDI on the CO₂ emissions of recipient countries, we re-estimated the model using the lagged term of the independent variable; the empirical results are reported in Table 6. The results indicate that the coefficient sign and significance of the lagged OFDI remain consistent with those of the baseline regression, suggesting that our findings are robust and not merely coincidental outcomes arising from contemporaneous correlations among the variables.

6. Further Discussion: B&RI Versus Non-B&RI Countries

Table 7 presents a comparison of the top five recipient countries/regions in 2019 between B&RI and non-B&RI countries. Clearly, while China's OFDI patterns in countries located within the B&RI mostly include investments in infrastructure and the acquisitions of energy and power industries, investments in non-B&RI countries have mainly focused on finance, technology, and entertainment industries. It is interesting to note that Chinese state-owned firms carry out most of the investment in B&RI countries, and they are also the leading operators in the energy and power industries. However, the pattern of OFDI is different for non-B&RI countries. The differences in China's OFDI between B&RI and non-B&RI countries have important implications for recipient countries' CO₂ emissions.

Since this study only covers 68 countries, the criterion used to classify the sample into B&RI (33) and non-B&RI countries (35) is whether each country officially signed the cooperation document for jointly building the "Belt and Road Initiative" in 2019. Table A3 in Appendix A summarizes B&RI and non-B&RI countries, and Table 8 depicts the results of the 3SLS model. Table 8 shows that the scale effect is positive in B&RI countries and negative in non-B&RI countries. This disparity may stem from systemic divergences in investment structure, cooperative mechanisms, and host-country absorptive conditions. In B&RI countries, which are typically developing economies characterized by multidimensional capital shortages, China's OFDI is predominantly channeled into infrastructure connectivity, production capacity cooperation, and other physical investment projects. By leveraging institutional synergies from policy coordination and infrastructure connectivity, such investment effectively alleviates the recipient countries' savings and foreign exchange gaps, thereby unlocking sustained long-term economic growth momentum. In contrast, non-B&RI countries are mainly advanced economies or single-resource-dependent nations, where China's OFDI is largely concentrated on technology-seeking M&As and pure resource extraction, which tend to be short-term and profit-driven and feature shorter localized value-added chains. The higher institutional distance and more stringent foreign investment regulations in these countries give rise to notable crowding-out effects on local investment and international capital. Together with substantial cross-border repatriation of corporate profits, the growth dividends from capital inflows are largely offset by

multiple countervailing mechanisms, ultimately suppressing the host country's overall economic expansion.

Table 7. A comparison of the top five recipient countries/regions in 2019 between B&RI and non-B&RI countries.

No.	B&RI Countries		Non-B&RI Countries	
	Recipient Country	Main Investment Industry	Recipient Country	Main Investment Industry
1	Singapore	Wholesale and retail trade; Leasing and business services	US	Manufacturing; Leasing and business services; Financial services
2	Russia	Mining; Manufacturing	Australia	Mining; Real estate; Leasing and business services; Financial services
3	Indonesia	Manufacturing; Construction; Electricity, heat, gas and water production and supply	UK	Leasing and business services; Manufacturing
4	Malaysia	Construction; Manufacturing; Energy (gas, alternative)	The Netherlands	Manufacturing; Information transmission, software and IT services
5	Laos	Transportation, storage and postal services; Electricity, heat, gas and water production and supply; Agriculture, forestry, animal husbandry and fishery	Luxembourg	Scientific research and technology services; Finance; Residential services; Wholesale and retail

Table 8. Regression results between B&RI and non-B&RI countries.

Dep. Var.	B&RI Countries				Non-B&RI Countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnCO ₂	lnScale	lnTech	lnStru	lnCO ₂	lnScale	lnTech	lnStru
lnOFDI		0.015 *** (3.48)	−0.023 *** (−2.71)	−0.041 *** (−7.43)		−0.013 *** (4.91)	0.013 *** (4.57)	0.006 (1.52)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
lnScale	1.151 *** (92.63)				1.256 *** (45.20)			
lnTech	−1.042 *** (−62.37)				−1.186 *** (−18.04)			
lnStru	0.047 *** (2.61)				0.008 (0.17)			
_Cons	−17.936 *** (−55.82)	22.181 *** (40.60)	7.843 *** (34.37)	5.669 *** (4.39)	−19.593 *** (−21.66)	21.619 *** (30.22)	10.084 *** (13.37)	6.600 *** (3.58)
Region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test	1603.78	99,999.00	451.32	175.87	2901.53	99,999.00	844.59	220.42
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Obs.	627	627	627	627	665	665	665	665

Notes: *** indicates statistical significance at the 1% level. The values in parentheses are z-values.

Regarding the technical effect, the coefficient of China's OFDI in B&RI countries is negative, while that in non-B&RI countries is positive, suggesting that China's OFDI inhibits energy efficiency in B&RI countries but promotes it in non-B&RI countries. A plausible

explanation lies in the sectoral composition of investment. In B&RI countries, China's OFDI is heavily concentrated in high-energy-consuming infrastructure and resource extraction sectors such as railways, ports, thermal power, and mining, which substantially expands the recipient economy's aggregate energy consumption in the short term. Concurrently, the weak human capital, lax environmental regulations, and limited industrial absorptive capacity in these countries further undermine energy efficiency. In non-B&RI countries, by contrast, China's OFDI is primarily oriented towards strategic asset-seeking M&As, high-end services, and green technology innovation investments. Combined with the Porter effect induced by stringent energy regulations in developed economies, this pattern significantly enhances the recipient country's energy efficiency.

China's OFDI has a restraining effect on the industrial upgrading of B&RI countries, likely because B&RI countries usually have middle- and low-income economies, with obvious shortcomings in industrial foundation, human capital, and institutional absorption capacity. Additionally, China's investment in these countries is mainly concentrated in resource extraction, infrastructure, and mature labor-intensive manufacturing industries, resulting in a vertical and low-end industrial transfer pattern. The insignificant impact on non-B&RI countries might be because they have stronger industrial resilience and can withstand or absorb the short-term fluctuations brought about by foreign investment.

Overall, the net effect of China's OFDI on B&RI countries' CO₂ emissions is positive, while that in non-B&RI countries is negative. Due to implementation of the "Going-Out" strategy, especially the B&RI strategy, numerous Chinese companies have invested in B&RI countries. Among these, the majority are state-owned companies (e.g., PetroChina and Sinopec) that concentrate on the secondary industry (e.g., petroleum exploration and mining) and thus add to the recipient countries' CO₂ emissions. Additionally, although Chinese non-state-owned enterprises invest more globally (see Figure 2), there is a massive difference in investments between state-owned and non-state-owned companies in B&RI countries. Most investments in B&RI countries come from state-owned enterprises. For non-B&RI countries, there is a negative relationship between OFDI and CO₂ emissions.

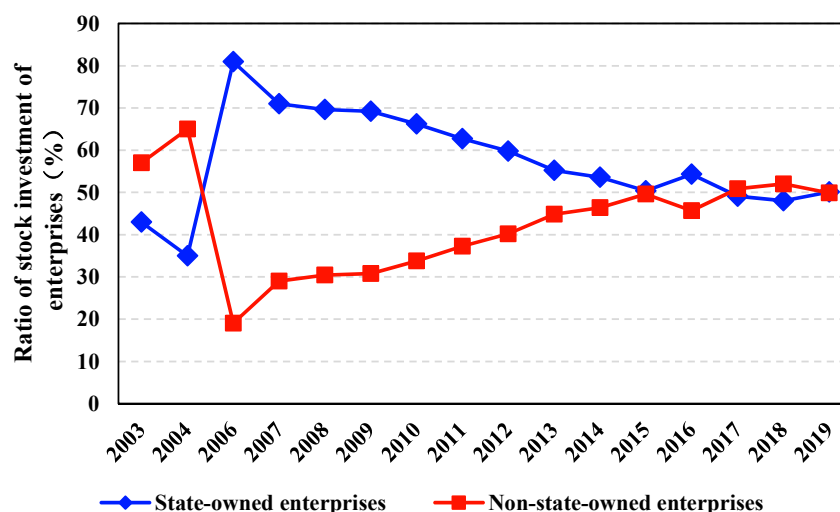


Figure 2. The proportions of China's OFDI stocks of state-owned and non-state-owned enterprises.

7. Conclusions and Policy Implications

7.1. Conclusions

To verify whether China's OFDI affects the global greenhouse effect, this study investigates the three major effects of China's OFDI (i.e., scale, technical, and structure effects) on recipient countries' CO₂ emissions by the simultaneous equation model, based on balanced panel data for 68 global countries from 2003 to 2021. Also, the 68 countries are divided

into two categories (i.e., B&RI and non-B&RI countries) for empirical analysis. The main findings of this study are as follows:

- (1) The net effect of China's OFDI on CO₂ emissions, calculated as the sum of the scale, technical, and structural effects, was found to be positive across the globe. Specifically, the total marginal effect of OFDI on CO₂ emissions is 0.108917, which is significantly greater than 0, suggesting the positive impact of China's OFDI on CO₂ emissions.
- (2) The mechanism analysis further clarifies the sources of this positive effect. Specifically, this positive effect is primarily attributable to the emissions arising from OFDI-induced economic expansion (scale effect) and industrial upgrading retardation (structure effect), which are not fully compensated by the emission reductions resulting from improved energy efficiency (technical effect).
- (3) The heterogeneous analysis reveals that the net effect of China's OFDI on CO₂ emissions—synthesized from the scale, technical, and structural channels—varies sharply across regions. The net marginal effect is positive for B&RI countries, indicating an exacerbating impact on CO₂ emissions, whereas it turns negative for non-B&RI countries, suggesting a mitigating effect. Among them, we discover an essential conclusion that China's OFDI will restrain the industrial upgrading in the B&RI countries.

7.2. Policy Implications

According to the above findings, several policy implications are suggested:

First, to counteract the positive carbon-emission effects arising from the scale and structural effects, China's OFDI layout should be optimized in a tiered and differentiated manner. Specifically, the Ministry of Commerce and the National Development and Reform Commission should jointly establish a green access negative list for overseas investment projects, strictly restricting new OFDI in thermal power, high-energy-consumption mining, and obsolete building materials production capacity across all recipient countries. Concurrently, a dedicated green investment subsidy scheme should be introduced, providing interest subsidies for OFDI in sectors such as photovoltaics, wind power, energy storage, and digital services, thereby incentivizing low-carbon outward investment.

Second, the technical effect is the only pathway with emission-reduction potential; however, its current mitigation contribution remains insufficient to offset the emission increases driven by the scale and structural effects. To address this, a special Belt and Road Green Technology Cooperation programme should be established, with priority support for joint R&D and technological collaboration in renewable energy, smart grids, and other clean energy fields. In parallel, China should actively promote the internationalization of its green technology standards. By embedding China's competitive technological standards—notably in photovoltaics, wind power, and electric vehicles—into overseas investment projects, Chinese green technologies can become a viable option for host countries' low-carbon transitions. It is important to note that the absorption and application of green technologies are highly dependent on the recipient country's human capital and its pool of science and technology talent. Accordingly, a Green Technology and Sustainable Development scholarship programme should be established for B&RI countries, offering a certain number of study and training places each year to outstanding students from recipient countries to pursue academic programmes or short-term training in China. This will help recipient countries cultivate their own green technology professionals. In addition, in collaboration with domestic universities and research institutions, an online green technology education platform tailored to B&RI countries should be developed. Furthermore, the industry-education integration model should be promoted in B&RI countries, linking vocational training with the practical needs of green investment projects.

Third, to counteract the adverse structural effect—namely, the suppression of industrial upgrading in B&RI countries—policy interventions should extend beyond technology-oriented cooperation and directly address the sectoral composition and quality of China's OFDI. China's OFDI should be encouraged—through fiscal incentives and bilateral investment agreements—to flow more into the tertiary industries of B&RI countries, such as digital services, information technology, and modern logistics, which typically feature lower emission intensity and higher technological spillovers. Moreover, for OFDI that necessarily enters the secondary industry, policies should incentivize Chinese firms and local partners to jointly develop and adopt cleaner manufacturing processes and upgrade existing production facilities, thereby avoiding the lock-in outdated, energy-intensive capacity. Furthermore, we also suggest the establishment of a sector-oriented “green investment” directory to guide OFDI toward industries that facilitate industrial upgrading rather than retard it.

7.3. Research Limitations and Future Directions

Despite the theoretical and empirical contributions of this study, two notable limitations warrant further investigation. First, the empirical analysis is confined to a linear specification, presupposing a monotonic effect of China's OFDI on host-country CO₂ emissions. This assumption, however, may obscure potential threshold effects and structural breaks. To address this, future research will employ panel threshold models to examine how the emission impact of OFDI varies nonlinearly with recipient-country attributes—such as income level, institutional quality, and absorptive capacity—thereby revealing the conditional nature of the OFD-CO₂ link. Second, our study mainly treats each host country as an isolated unit, implicitly neglecting spatial interdependence in both CO₂ emissions and OFDI flows. Given the transboundary nature of pollution and the regional spillovers inherent in industrial relocation, energy trade, and technology diffusion, subsequent studies will incorporate spatial econometric frameworks. This will allow for a systematic assessment of how China's OFDI influences emissions not only within each recipient country but also across neighboring economies, offering a more comprehensive understanding of its regional and transnational environmental implications.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

BP	British Petroleum
B&RI	Belt and Road countries
CO ₂	Carbon dioxide
EKC	Environmental Kuznets curve
FDI	Foreign direct investment
GDP	Gross domestic product
OFDI	Outward foreign direct investment
R&D	Research and development
2SLS	Two-stage least square
3SLS	Three-stage least square
SO ₂	Sulfur dioxide

Appendix A

Table A1. Results of the multicollinearity test.

Variables	Carbon Effect	Scale Effect	Technical Effect	Structure Effect
<i>lnScale</i>	1.15			
<i>lnTech</i>	1.52			
<i>lnStru</i>	1.40			
<i>lnOFDI</i>		1.06	1.02	1.44
<i>lnUrb</i>		1.18	1.90	1.91
<i>lnTra</i>		1.21		1.67
<i>lnLab</i>				2.42
<i>lnPgdp</i>			1.89	2.35
<i>lnDen</i>		1.24		
Mean VIF	1.36	1.17	1.60	1.96

Table A2. Results of the cross-sectional dependence test.

Tests	Carbon Effect	Scale Effect	Technical Effect	Structure Effect
Breusch-Pagan LM test	10912.02 ***	10429.78 ***	10895.49 ***	9230.89 ***
Pesaran CD test	21.514 ***	23.629 ***	18.557 ***	10.694 ***

Notes: *** indicates statistical significance at the 1% level.

Table A3. The classification of the B&RI countries and non-B&RI Countries.

Classification	Countries
B&RI countries	The United Arab Emirates, Oman, Azerbaijan, Egypt, Pakistan, Belarus, Bulgaria, Poland, the Russian Federation, the Philippines, Kazakhstan, Czech Republic, Croatia, Latvia, Romania, Malaysia, Bangladesh, Saudi Arabia, Sri Lanka, Slovenia, Thailand, Turkey, Turkmenistan, Ukraine, Uzbekistan, Singapore, Hungary, Iraq, Iran, Israel, India, Indonesia, Vietnam
Non-B&RI Countries	Algeria, Argentina, Ireland, Austria, Australia, Brazil, Belgium, Denmark, Germany, Ecuador, France, Finland, Colombia, South Korea, the Netherlands, Canada, Luxembourg, the United States, Peru, Morocco, Mexico, South Africa, Norway, Portugal, Japan, Sweden, Switzerland, Cyprus, Trinidad and Tobago, Spain, Greece, New Zealand, Italy, Britain, Chile

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