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Study on the Impact of China's Outward FDI on Carbon Emissions in the Countries Along the Belt and Road

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ABSTRACT

With the strengthening of China's economic power and the further implementation of China's open-door policy, China's outward investment has increased year by year. Some international comments are only concerned about the former and there are some public opinions about China's outward investment threatening the host country's environmental quality. This paper takes the carbon emissions of 49 countries along the "Belt and Road" and the acceptance of China's outward FDI as samples, studies the impact of China's outward FDI on the carbon emissions of the relevant countries, and comes to the conclusion that: China's outward FDI is a major factor in China's economic development. It is concluded that China's OFDI increases the total carbon emissions of the countries along the Belt and Road while decreasing the carbon intensity, and the impact is carried out through the three major paths of economic scale, technological level and structural effect.

KEYWORDS

China's Outward Foreign Direct Investment; Carbon Dioxide Emissions; Belt and Road; Carbon Intensity

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1. Introduction

Since China's accession to the World Trade Organization, China's economy has been integrated into the globalization process, and China's economic development has made achievements that have attracted the world's attention. Since China's GDP surpassed Japan's in 2010, China's economy has been ranked second in the world in terms of size, and in 2023, China's GDP will reach US$1.837 billion, which is far more than the US$442 million that is the third largest in terms of economy size. At the same time, the scale of China's outward foreign direct investment (OFDI) has also been growing rapidly, according to the "China's Outward Foreign Direct Investment Bulletin of All Years", the amount of China's outward foreign investment flow has remained in the top three in the world since 2012, and by 2022, China's stock of outward foreign direct investment will reach 2.96 trillion U.S. dollars, ranking the third in the world. In the process of expanding the scale of China's outward FDI, the investment destinations are also changing dynamically, especially since China put forward the Belt and Road Initiative in 2013, and China's outward FDI has stepped up its investment in infrastructure, energy exploitation, digital construction and other aspects in the countries along the route, and in this process, the expansion of the scale of the economy of the host country is accompanied by an increase in carbon emissions.With the increasingly serious problem of global climate change, the control and reduction of carbon emissions have become the focus of extensive attention by the international community. The environmental, economic and social problems caused by global warming have prompted governments, international organizations and enterprises to strengthen the management and governance of carbon emissions. According to the common timeframe of the Paris Agreement, parties are required to submit a new round of Nationally Determined Contributions (NDCs) for 2035 by 2025 (Wang Hailin et al., 2024). Against this backdrop, the Chinese government has proposed a "dual-carbon" goal, whereby green production and living styles are widely formed and carbon emissions are steadily decreasing after peaking, which is one of the overall goals of building a comprehensively modernized socialist powerhouse (Lei et al., 2024). Achieving carbon peak by 2030 and carbon neutrality by 2060 has further boosted China's response to climate change, with the aim of achieving carbon neutral by 2060. This goal of achieving carbon peaking by 2030 and carbon neutrality by 2060 has further promoted China's transformation in addressing climate change. The "Belt and Road" initiative is a major international cooperation initiative proposed by China in 2013, aiming to promote economic cooperation and common development between China and the countries along the route through policy communication, facility connectivity, smooth trade, financial integration, and people-to-people communication (Tan Xiaofen et al., 2024). It has been shown that FDI inflows may affect the environmental quality of host countries through technology transfer, industrial upgrading, and infrastructure construction. On the one hand, FDI can significantly reduce pollutant emissions and improve regional environmental quality (Qin Xiaoli, 2016); on the other hand, foreign capital inflows may also exacerbate the host country's energy consumption, especially the economic model that relies on fossil energy sources, thus increasing carbon emissions, and China's outward FDI will exacerbate the greenhouse effect of the host country, but it will effectively reduce the host country's carbon emission intensity (Dong Kangyin et al., 2023) China's outward FDI will exacerbate the host country's greenhouse effect, but will effectively reduce the host country's carbon intensity (Dong Kangyin et al. Therefore, the specific impact of China's investment in countries along the Belt and Road on carbon emissions is still controversial, and the effects of investment may differ significantly across regions and industries.

Based on the above, what is the impact of China's outward investment on carbon emissions in countries along the Belt and Road? What are the impact paths and channels? What are the differences in the relationship between China's OFDI and carbon emissions in countries along the "Belt and Road" at different levels of development and innovation? "Does the Belt and Road Initiative have an impact on this relationship? Exploring these questions is conducive to a comprehensive and in-depth analysis of the characteristics and paths of the impact of China's OFDI on the carbon emissions of the countries along the Belt and Road, and provides theoretical decision-making support

for China's adjustment of OFDI destinations and investment industries, and the realization of dual-carbon development with the countries related to the Belt and Road. It will provide theoretical decision-making support for China to adjust its OFDI destinations and investment industries, and realize dual-carbon development with the countries along the Belt and Road.

2. Literature Review

Walter (1979) and others put forward the theory of "pollution sanctuary", which argues that developing countries will take over the industries of developed countries and bring a large amount of pollution at the same time, which makes the host country increase the environmental pollution of its own country at the same time of obtaining the economic benefits.Copel and (2017) were the first to introduce this issue into the analysis of environment and investment. investment by analyzing the potential impact of trade and investment liberalization on the host country's environment. They found that under the influence of investment liberalization, developing countries mostly accept highly polluting industries from developed countries, and environmental pollution in developed countries decreases while developing countries increase. After that Han-solLee (2021), Li Chuangxiang (2020) and others confirmed that OFDI would aggravate environmental pollution in host countries.

The counterpart to the "pollution haven" hypothesis is the "pollution halo" hypothesis, which Reppelin (1999) verified by analyzing industrial technology factors. Reppelin (1999) verified the "pollution halo" hypothesis by analyzing industrial technology factors and argued that the inflow of foreign investment does not bring high pollution, but reflects the environmental quality of the host country. Sheng Ni (2022) found in China's outward FDI in ASEAN countries that China's FDI in ASEAN countries did not aggravate environmental pollution in ASEAN countries. Liu Chao (2022) found that China's outward FDI in countries along the Belt and Road significantly suppressed the growth of carbon emissions in countries along the Belt and Road.

At present, academic research on the environmental effects of China's outward foreign direct investment (OFDI) mainly focuses on two aspects: first, the reverse environmental spillover effects on home countries, and second, the environmental impacts on developed economies in host countries. This research pattern has an obvious sample selection bias. As a matter of fact, most of the countries along the Belt and Road, as important destinations for China's outward FDI, belong to low- and middle-income developing countries, which often face problems such as insufficient environmental regulatory capacity and weak environmental governance infrastructure, and at the same time are at the developmental stage of industrialization with a strong demand for energy and natural resources. At the same time, they are also in the development stage of industrialization with strong demand for energy and natural resources. Therefore, this paper focuses on developing countries on the Belt and Road, which not only helps to test the applicability of the pollution shelter hypothesis in the context of South-South cooperation, but also provides new empirical evidence for assessing the environmental externalities of China's outward investment. In terms of research content, this paper constructs a more complete theoretical analytical framework based on existing literature to examine the impact mechanism of China's outward foreign direct investment (OFDI) on carbon emissions in the Belt and Road countries. Firstly, by constructing a system of linkage equations, we not only examine the direct effect of OFDI on carbon emissions, but also depict the indirect effect through the intermediary channels of technological innovation, industrial structure upgrading and economic growth, so as to reveal the transmission mechanism of OFDI's impact on carbon emissions. Second, considering the significant differences in the level of economic development, institutional quality and resource endowment of the countries along the Belt and Road, this paper further introduces heterogeneity analysis to examine the differences in the carbon emission response of host countries with different characteristics in the face of China's OFDI. This multi-dimensional and multi-level empirical research framework not only enriches the theory of environmental effects of South-South investment, but also provides solid empirical support to refute the Western "pollution shelter" argument. The results of the study show

that China's OFDI actually promotes the green development transformation of host countries through technology spillover and industrial upgrading effects, which contrasts sharply with the image of “environmental destroyer” portrayed by the Western media.

3. Theoretical Analysis and Research Hypothesis

3.1. Definition of the concept

In order to effectively examine the impact of OFDI on carbon dioxide emissions in the countries along the Belt and Road Initiative and to explore the influence mechanism and internal path between the two, it is necessary to accurately define the concepts of OFDI, carbon dioxide emissions, and carbon dioxide emissions, so as to lay the foundation for a subsequent comprehensive study. “Therefore, it is necessary to accurately define the concepts of OFDI, CO2 emissions, and the Belt and Road Initiative in order to lay the foundation for a comprehensive study.

3.1.1. Level 3 heading

At present, domestic and foreign scholars have basically reached a consensus on the understanding of the concept of OFDI. The more widely recognized definition is put forward by the United Nations Conference on Trade and Development (UNCTAD), which states that a long-term cooperation and win-win relationship is formed between an investment subject of one country or region and an investee subject of another country, characterized by cross-border flow of capital, substantial transfer of management rights, continuous sharing of investment income, and joint assumption of risks and benefits. The definition adopted by China's OFDI research was put forward by the Ministry of Commerce (MOFCOM), i.e.: China's local enterprises or individuals conduct outward investment activities in the form of physical or non-physical assets in other countries or regions outside of China, as well as in China's Hong Kong, Macao, and Taiwan regions, and at the same time, they hold the right to manage and administer the enterprises in the process of investment. Its core connotation includes: (1) the scope of investment subjects: domestic enterprise entities, individuals with investment capacity, other economic organizations, (2) the form of investment: investment in physical assets, including plant, equipment, raw materials, etc., and investment in non-physical assets, including technology, brands, patents and other intellectual property rights. (3) Investment destinations: other sovereign countries outside China, Hong Kong, Macao and Taiwan, and economies along the“One Belt, One Road” routes. (4) Requirement of control: to obtain the actual management rights of the invested enterprise, to have the influence of major decision-making, and to enjoy the corresponding right of income distribution. This paper discusses the effect of OFDI on carbon emissions in the countries along the Belt and Road, and the sample data are from the yearbooks and bulletins of the Ministry of Commerce of China and the China Bureau of Statistics of China, so the definitions of OFDI in this paper are from the Ministry of Commerce of China and the China Bureau of Statistics of China. Ministry of Commerce.

3.1.2. Carbon footprint

In recent years, the international community has become increasingly concerned about climate change, as an important part of the global greenhouse effect, carbon dioxide emissions accounted for as much as 76%, therefore, in order to fundamentally solve the greenhouse effect problem, reduce carbon dioxide emissions is an urgent problem, a variety of carbon dioxide emission policies have been implemented, such as the evolution of the international climate governance framework, the innovation of national emission reduction policy tools, including carbon Pricing mechanism (carbon tax, carbon trading), energy structure optimization policies, industrial low-carbon transformation incentives, clean technology research and development support policies. This paper selects representative sample data from 49 countries along and “Belt and Road” routes, which belong to the national level,

mainly based on the following considerations: the representativeness of geographic distribution, the diversity of economic development stages, and the differences in industrial structure, The typicality of energy consumption patterns. Considering the availability of the data used in this paper, as well as the correlation characteristics with the required variables, this paper refers to the carbon dioxide emissions data of each country published by the U.S. Energy Information Administration, which has the following characteristics: data reliability: the adoption of a unified international accounting standard, temporal continuity: a long historical data series, and consistency of caliber: comparable with the data of other international agencies. Scope of carbon emission accounting: fossil energy combustion, including coal and coke consumption, natural gas use, oil and its derivatives consumption, industrial production processes, energy conversion activities. National data are obtained from official national statistical institutes and relevant energy sectors. The use of these data helps to: accurately assess the current status of carbon emissions in each country; identify potential and opportunities for emission reductions; analyze the effectiveness of policies; and make targeted recommendations.

3.1.3. Countries along the "Belt and Road" Route

The Belt and Road Initiative (a combination of the Silk Road Economic Belt and the 21st Century Maritime Silk Road), proposed by China in 2013, covers both traditional land and maritime trade routes. The Belt and Road Initiative (the "Silk Road Economic Belt" and the "21st Century Maritime Silk Road" together) covers traditional land and sea trade routes, and aims to promote the process of global economic integration by strengthening infrastructure connectivity, economic and trade cooperation, and policy coordination among the countries along the route. In March 2015, the State Council of China issued the "Vision and Actions for the Promotion of the Co-construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road," which signifies that the Initiative has risen to the level of a national strategy, and put forward the economic The concept of cooperation. From an economic perspective, the goal is to increase the productivity and economic growth potential of countries along the route by enhancing infrastructure development, promoting trade facilitation, expanding direct investment and strengthening regional economic integration. Improved infrastructure not only shortens logistics time and reduces transportation costs, but also improves market efficiency by eliminating information asymmetry and facilitates the free flow of capital, technology and labor within the region. As of the end of June 2023, China has signed more than 200 cooperation documents on the construction of the Belt and Road with 152 countries and 32 international organizations. "The Belt and Road Initiative can be interpreted as a large-scale international public good, indicating that the Belt and Road Initiative has become a multilateral cooperation platform on a global scale, which not only promotes the depth and breadth of transnational cooperation, but also contributes to the improvement of the global economic governance system. It has not only promoted the depth and breadth of transnational cooperation, but has also made a positive contribution to the improvement of the global economic governance system. Through this multilateral cooperation mechanism, the Initiative promotes policy coordination, economic complementarity and resource-sharing among countries, helping to build a new pattern of globalization that is more open, inclusive and mutually beneficial. Referring to the research of Lu Yue et al. (2019), this paper defines the countries along the "Belt and Road" as the 65 countries that are connected to the Pacific Ocean in the east and the Baltic Sea in the west, running through the three continents of Asia, Europe and Africa. These countries have important geographic locations, different resource endowments, and varying levels of economic development, so the implementation path and effects of the "Belt and Road" initiative vary significantly from country to country. In addition, due to the serious lack of data for some countries, the research sample in this paper mainly focuses on the 49 countries that joined the initiative earlier and are representative in terms of economic scale and affluence. By analyzing the data from the sample of these countries, we can better understand the impact mechanism and transmission path of the Belt and Road Initiative on the economic development of each country.

3.2. Theoretical mechanisms

3.2.1. EKC curve

Grossman and Krueger (1991) first verified the relationship between environmental quality and per capita income, arguing that pollution levels tend to increase and then decrease as GDP per capita increases, which was later summarized by Panayotou (1993), who referred to this relationship as the Environmental Kuznets Curve (EKC). The formula is expressed as:

$$E_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + \beta_3 x_i^3 + \beta_4 z_i + e_i \quad (1)$$

Where E refers to the environmental indicators, X is the per capita income, and Z is other control variables that affect the environmental indicators. The curve reveals the "inverted U-shaped" curve relationship between environmental pollution and per capita income, i.e., at the stage of a country's economic development level is relatively backward, a country usually sacrifices the environment in exchange for economic development, but with the increasing level of per capita income, people's concept of environmental protection is increasingly strengthened and the technological level is constantly improved. Under the influence of multiple factors, the government will formulate and implement more demanding environmental policies and standards, so that pollution-intensive industries will be gradually eliminated, and the intensity of local environmental pollution will continue to decline, and will gradually decrease with the further increase in per capita income level.

The EKC curve analyzes the relationship between environment and income, but the model has some limitations in the complex context of reality. Firstly, the relationship between environment and income is not always inverted U-shape, Zhao Xiaokang, Li Jianmin, Wang Jinying et al. (2005) proved through empirical research that the EKC characteristics between environmental quality and per capita income in China are not significant. Secondly, the EKC model has indicator limitations, such as the loss of biodiversity, atmospheric changes and other difficult to measure environmental indicators are difficult to apply to the EKC. thirdly, the environmental pollution of different countries and different stages of development is related to a variety of factors, and the increase in per capita income does not necessarily improve the ecological environment. In addition, the improvement of environment is not only under the condition of economic development, if the development of the economy at the same time to introduce effective environmental protection policy, can realize the two go hand in hand.

However, in the long-term research process, researchers' criticism of EKC has not shaken its theoretical foundation, which also shows that EKC has its own value. Relevant research can combine with the real foundation, optimize the selection of indicators, and deepen the research of EKC theory.

3.2.2. The "pollution haven" hypothesis

The "pollution haven" hypothesis, which was put forward by scholars studying the relationship between trade and the ecological environment, refers to the fact that countries, in order to mitigate environmental degradation in their own countries, will gradually transfer pollution-intensive industries to countries or regions with a relatively low degree of environmental regulation. Various countries due to historical accumulation and resource endowment constraints lead to significant differences in the level of economic development, for low-income countries, which itself has the advantage of a favorable ecological environment, in order to accelerate the country's economic development and expansion of the scale of the cost of sacrificing the environment to promote the inflow of capital from the economically developed countries, and reduce the level of its environmental regulation, which is for the "pollution sanctuary" hypothesis. This provides an opportunity for research on the "pollution shelter" hypothesis.

Many scholars have studied that OFDI increases the carbon emissions of host countries, i.e., proving the "pollution haven" hypothesis. Sun (2017) used time series data from 1980-2002 to explore whether the "pollution

haven" hypothesis in China based on the ARDL methodology. Sun (2017) used time series data from 1980 to 2002 to investigate whether the "pollution refuge" hypothesis exists in China based on the ARDL method. The empirical results indicate that the gradual increase in the amount of foreign investment introduction in China exacerbates the greenhouse effect in the country, a finding consistent with Cheng's (2020) findings on haze pollution. Cheng (2020) empirically explores the spatial PM2.5 emission of FDI on China's PM2.5 emissions using spatial dynamic panel data with statistical data of 285 Chinese cities in the period of 2003-2016 as an example. effect. The results show that the rapid growth of FDI exacerbates the level of haze pollution at the city level in China, which confirms the validity of the "pollution refuge" hypothesis.Bulus and Koc (2021) examine the actual effects of FDI and government expenditures on environmental quality with the help of a sample of Korean statistical data for the period of 1970-2018 by adopting the ARDL method. The actual role of FDI and government expenditure on environmental quality. The results show that FDI inflows lead to a significant increase in per capita carbon emissions, which confirms the validity of the hypothesis.

3.2.3. The "pollution halo" hypothesis

The "pollution halo" hypothesis, which argues that international direct investment by firms can significantly improve the environment of host countries, has also been tested. On the one hand, the technological and managerial know-how of multinational enterprises is brought to the host country as part of their international FDI, resulting in technological spillovers that can increase labor productivity and reduce energy consumption in production in the host country. On the other hand, under the high environmental standards of the home country, multinational enterprises often have cleaner production technologies. This combination of factors makes OFDI by home country firms favorable to the improvement of the host country's environment.

Many scholars have verified this hypothesis. Birdsall and Wheeler (1993) argue that trade and international FDI introduce advanced clean technologies into developing countries and promote environmental improvement, while Eskel and Harrision (2003) argue that MNEs pay more attention to ecological protection than host-country firms, and have high environmental standards and green production standards, which is conducive to promoting the improvement of the host country's environment.Kisswani and Zaitouni (2021) used the ARDL method to test the potential role of FDI on carbon emissions, and the empirical results provide support for the pollution halo hypothesis in Malaysia and Singapore. In addition to verifying the effect of FDI on carbon emissions in a particular country, Abid and Sekrafi (2021) focused on the direct and indirect effects of trade openness on environmental degradation in 31 developed and 100 developing countries over the period of 1980-2006 based on the generalized method of moments estimation. The empirical results show that the "pollution paradise" hypothesis applies only to developing countries, while the "pollution halo" hypothesis applies to developed countries.

3.3. Theoretical mechanisms

3.3.1. Derivation of theoretical mechanisms

In order to theoretically deduce the specific internal mechanism of the impact of China's OFDI on the host country's carbon emissions, this paper constructs the following theoretical model, and its corresponding assumptions are as follows:

(1) Assume that there are only two kinds of goods in the economy: green products and polluting products. Polluting products are denoted by X, and clean products are denoted by Y.

(2) It is assumed that the technology and equipment adopted in the production process of clean products and polluting products are different, and the carbon emission intensity brought by the two products is also different, with significant differences. Therefore, this paper sets that green products adopt decarbonization technology, do

not produce greenhouse effect gases and do not promote carbon dioxide emissions, and relatively, the production of polluted products does not adopt decarbonization technology, which produces greenhouse gases and enhances carbon dioxide emissions.

(3) Set the price of the polluting product as Px and the price of the green product as Py, and both have a production function with constant returns to scale. At the same time set both in the production process only use labor L and capital K two factors of production, and (Kx/Lx) > (Ky/Ly).

(4) This paper adopts the relevant conclusions of the Heckscher-Ohlin (H-O) theory that polluting products usually have market and capital-intensive characteristics, while green products have a large number of labor factors. Therefore, it is set that X is a polluting product and Y is a green product.

According to the above four settings, the production function about carbon emission, pollution products and green products can be constructed with the following formula:

$$X = (1-\varphi)F(Kx,\ Lx) \tag{2}$$

$$Y = G(Ky,\ Ly) \tag{3}$$

$$CO_2 = \omega(\varphi)F(Kx,\ Lx) \tag{4}$$

X represents the total output of the polluting product X, F(Kx, Lx) is the production function of the polluting product X, and φ denotes the resource allocation of the sector that produces the polluting product X in carrying out the measures related to the promotion of carbon emission reduction, and it represents the proportion of the factors such as technology and capital that the enterprises producing the polluting product need to use in carrying out the behavior of carbon emission reduction to the total amount of elements needed in the whole production process. y represents the total output of the green product Y=G (Ky, Ly) denotes the production function of the green product Y. Since the green product Y adopts decarbonization technology and does not produce carbon dioxide, the production function of CO_2 in Eq. (3.4) CO2=ω(φ)F (Kx, Lx) is only related to the polluted product F(Kx, Lx), in which ω(φ) denotes the intensity of carbon emission, and ω(0)>0, ω'(0)<0, ω''(0)>0, so ω(φ) is a monotonically decreasing function.

From equation (2), it can be seen that the output of polluting product X is negatively correlated with φ, that is, the larger the proportion of factors such as technology and capital that enterprises producing polluting products need to use in the carbon reduction behaviors accounts for the total amount of elements needed in the whole production process, the lower the total output of X. From equation (4), it can be seen that the CO2 is related to the polluting product constant only. At the same time, a country's carbon emission intensity is also affected by a country's technological innovation, so set a country's technological progress as A, then refer to the conclusion of Copel and and Taylor (2003), the carbon emissions per unit of output value in the production of polluting products in the economy, i.e., carbon emission intensity. There is the following equation:

$$\omega(\varphi) = A^{-1}(1-\varphi)^{1/\alpha} \tag{5}$$

A is technological progress, indicating the level of green low-carbon technology, α is a parameter, 0<α<1, so the carbon emission intensity is negatively correlated with the level of technology.

Bringing equation (5) into equation (3) has:

$$CO_2 = A^{-1}(1-\varphi)^{1/\alpha}F(Kx,\ Lx) \tag{6}$$

Organizing equation (6) gives:

$$(\varphi) = \left[\frac{CO_2}{F(Kx,\ Lx)}\right]^{\alpha} \tag{7}$$

Equation (3.7) can be obtained by bringing (2.2) into (2.2):

$$\mathrm{X} = (A * CO_2)^{\alpha}\left[F(Kx,\ Lx)\right]^{1-\alpha} \tag{8}$$

From this, we can conclude that the output of the polluting product is determined by the effective pollution emission A*CO2 and the production function F(Kx, Lx).

According to the Economist's Law in economics, firms, as producers, follow the principle of profit maximization when they produce, and the economy in the setup has only two products, pollution product X and green product Y. Pollution product X produces pollution, so when the firm produces X, it needs to pay extra for the carbon emission, which generates extra cost. According to Coase's theorem, the government can intervene to make property rights clear when negative externalities are generated, which is done by the government's additional tax on manufacturers producing product X, assuming that this tax is λ. So firms will make the following decisions in order to achieve the goal of profit maximization:

(1) Set the price of labor L to be r and the price of capital K to be w to maximize profits by minimizing the cost of production when the production function F (Kx, Lx) is maximized:

$$\min \mathrm{wKx} + \mathrm{rLx} \tag{9}$$

$$\bar{x} = F(Kx,\ Lx) \tag{10}$$

The optimization conditions are:

$$\frac{\frac{\partial F}{\partial Kx}}{\frac{\partial F}{\partial Lx}} = \frac{r}{w} \tag{11}$$

(2) Combined with the above setting, the marginal cost of carbon dioxide emission brought by the production of X is λ, and the cost per unit of potential output is set to be C^F, combined with the equation (3.8), in order to achieve profit maximization, the enterprise will choose the optimal combination of A*CO2 and F(Kx, Lx) for production in the production process, to ensure that the cost of production of the unit of the polluting product X is the lowest, that is:

$$\min \lambda(A * CO_2) + C^F F(Kx,\ Lx) \tag{12}$$

$$\mathrm{X} = (A * CO_2)^{\alpha}\left[F(Kx,\ Lx)\right]^{1-\alpha} \tag{13}$$

A first order derivation of the above two equations has:

$$\frac{(\alpha)A * CO_2}{\alpha F(Kx,\ Lx)} = \frac{C^F}{\lambda} \tag{14}$$

So from equation (11) and equation (14), we can get: the ratio of marginal output of two factors is equal to the ratio of relative price of two factors.

According to the setting, the price of product X is Px, so the total revenue of producing product X is X*Px, and the total cost of producing product X is λ(A*CO2)+C^F F(Kx, Lx), so the total profit of producing product X is: TR-TC=Px- λ(A*CO2)+C^F F(Kx, Lx). For the sake of the study, it is assumed that the economy is in a perfectly competitive market, so the total economic profit is 0, so there is:

$$\mathrm{Px} = \lambda(A * CO_2) + C^F F\left(Kx,\ Lx\right) \tag{15}$$

Combining Eq. (14) with Eq. (15) organizes there:

$$CO_2 = \frac{\alpha \mathrm{X} * \mathrm{Px}}{A\lambda} \tag{16}$$

As shown in equation (16), the production of X moves in the opposite direction to the level of low-carbon technology A and is positively correlated with Px.

The economy as a whole produces two products, X and Y. Since Y does not produce carbon dioxide, the total production of the economy is Px*X+Py*Y, which is represented by Scale, i.e. Scale=Px*X+Py*Y, and the share of polluting product X in the total production=Px/ Px*X+Py*Y, which is represented by Stru, so that there is Stru= Px/ Px*X+Py*Y, and therefore For equation (16) organizing deformation has:

$$CO_2 = (Px * X + Py * Y) * \frac{\alpha}{A\lambda} * \frac{Px * X}{Px * X + Py * Y} \tag{17}$$

where α/Aλ represents the level of technology, denoted by Tech. Thus, equation (16) can then be expressed as:

$$CO_2 = Scale * Stru * Tech \tag{18}$$

As a result, the paper concludes that the total carbon emissions of an economy are composed of three components, which are the Scale effect (Scale), the Structural effect (Stru), and the Technological effect (Tech). The logarithmic treatment of (18) has:

$$lnCO_2 = lnScale + lnStru + lnTech \tag{19}$$

The derivation of equation (19) has:

$$\frac{dCO_2}{CO_2} = \frac{dScale}{Scale} + \frac{dStru}{Stru} + \frac{dTech}{Tech} \tag{20}$$

Therefore, this paper concludes that an economy's carbon emissions are jointly influenced by the scale effect $\frac{d\mathrm{Scale}}{\mathrm{Scale}}$, the structural effect dStru/Stru, and the technological effect $\frac{dTech}{Tech}$.

Continuing to derive both sides of equation (20) for OFDI, there are:

$$\frac{dCO_2}{CO_2}\frac{OFDI}{CO_2} = \frac{dScale}{Scale}\frac{OFDI}{Scale} + \frac{dStru}{Stru}\frac{OFDI}{Stru} + \frac{dTech}{Tech}\frac{OFDI}{Tech} \tag{21}$$

From this, the paper draws the final conclusion that the role of China's outward FDI on the carbon emissions of the inflowing countries can be decomposed into: scale effect, structural effect, and technological effect.

3.3.2. Theoretical assumption

Equation (21) shows that China's OFDI does not have a direct effect on the greenhouse effect in the host country, but has an indirect effect on the greenhouse effect in the host country by influencing the total scale, the optimized

level of industrial structure and the level of technological innovation in that country or region. The specific impact mechanism is analyzed as follows:

(1) Scale effect. The scale effect of OFDI refers to the fact that international direct investment helps host country enterprises to obtain funds for industrial scale expansion, which is conducive to the expansion of production scale of host country enterprises and helps host country to realize economic development and improve the level of per capita income, but at the same time, the expansion of industrial scale will lead to an increase in the amount of energy consumption required for the production, which in turn affects a country's carbon emissions. Many scholars have empirically examined this scale effect: Dai Dier, Li Zihao (2011) found that foreign direct investment (FDI) will promote the expansion of industry scale, which will lead to an increase in carbon emissions in China's industrial sector. Wang Daozhen and Ren Rongming (2011) also empirically tested this economic scale effect, and found that OFDI affects the scale of China's economy, which leads to an increase in China's carbon dioxide emissions. Specifically, the scale effect of OFDI can be analyzed from the following aspects.

First, with the further development of the host country's economy, the increased economic aggregate will promote the increase of social aggregate demand and social aggregate supply, which in turn will promote the continuous expansion of production scale and energy consumption, thus further stimulating the growth of carbon emissions. In addition, the EKC curve described above shows that at low levels of per capita income, the environment tends to deteriorate while per capita income increases, and when per capita income crosses a certain threshold, the environment improves as per capita income rises. From the point of view of economic scale, inward investment contributes to the development of the economy and brings about an increase in per capita income. For some developing countries, their economic development and per capita income levels are low, still on the left side of the EKC curve, when people's environmental awareness is weak, a country is still the main goal of economic development, in order to promote the rapid development of industrialization, the expansion of industrial scale has become an important goal of the government to attract foreign direct investment, which in turn promotes the growth of the economy and per capita income, and the expansion of industrial scale and the rise in per capita level may jointly lead to the deterioration of the environment, which will improve with the increase in per capita income. The expansion of industrial scale and the increase of per capita level may jointly lead to the increase of carbon emission in the host country. However, for some developed countries, their per capita income is already at a high level, i.e., on the right side of the EKC curve, at this time, people's demand for high quality of life promotes the enhancement of environmental protection awareness and the improvement of environmental standards, and with the improvement of per capita income, it further enhances, and the expansion of the scale of production and the increase of the per capita income caused by FDI affects the host country's carbon emission from both positive and negative sides together. Based on the above analysis, this paper puts forward research hypotheses:

Hypothesis 1: China's outward investment will promote the carbon emissions of countries along the “Belt and Road” through the scale effect.

(2) Technology effect. The technological effect of China's OFDI refers to the fact that the investee countries, in the process of introducing foreign investment, will introduce green and low-carbon technologies at the same time, so as to improve the host country's overall technological innovation capacity, thus contributing to the host country's carbon emission reduction. When Chinese enterprises invest abroad, they will combine with local enterprises to establish R&D companies and strengthen cooperation and transnational exchanges of low-carbon technologies. Relevant enterprises will gradually learn and master relevant technologies during the process of cooperative R&D, especially those host country enterprises with relatively backward technological level; the dissemination and spillover effect of technology will enhance the overall innovation level of host country enterprises, break through the original innovation obstacles and development bottlenecks, and thus accelerate Technology upgrading. Secondly, the investment of Chinese enterprises can prompt the host country to improve and upgrade the original backward

production facilities and business equipment, and at the same time, utilize more capital to carry out investment activities, and the research shows that only the host country with relatively high investment in R&D can improve the efficiency of domestic production. Increased innovation in saving limited natural resources can encourage enterprises to consume less energy to increase more output, while improving the energy efficiency and productivity of enterprises. Third, Chinese companies investing abroad usually have strong capital or advanced technology, which can provide sufficient capital for technological innovation in the host country, promote the development of the country's new energy industry, and improve the utilization of clean energy as well as the energy efficiency of the country as a whole.

Technological progress and improved energy efficiency can eliminate backward production technologies, reduce energy consumption and pollution emissions, and help upgrade and optimize the industrial structure, thus achieving the goal of carbon emission reduction. Looking at China's situation at this stage, China's contribution rate of science and technology has reached 58.5%, its comprehensive scientific and technological innovation capacity ranks 17th among all countries in the world, and the ratio of R&D expenditures to GDP has reached 2.15%, meanwhile, China is the first developing country in the world's top 20 innovative countries. The competitive advantages of Chinese enterprises in OFDI mainly come from technology-intensive industries such as power, railroad and communication, which usually have advanced clean production capacity, which largely reflects the scientific and technological strength and production technology of Chinese enterprises in OFDI, and can improve the innovation level of the host country in carbon emission reduction through the technological spillover effect, so as to promote the host country to reduce carbon emissions. Based on the above analysis, this paper puts forward the research hypothesis:

Hypothesis 2: China's outward investment will inhibit carbon emissions in the countries along the “Belt and Road” through the technology effect.

(3) Structural effect. The structural effect of China's OFDI emphasizes the interrelationship between the optimization of the existing industrial structure and environmental pollution. Specifically, when a country's dominant industry is pollution-intensive, environmental pollution will be relatively serious, while when a country's core industry is clean-intensive, the impact of environmental pollution will be smaller.

The role of Chinese enterprises' outward investment behavior on the industrial structure of investee countries mainly includes the following aspects: First, the outward investment activities carried out by Chinese enterprises can promote the improvement of production and operation efficiency of host countries through technology exchange and sharing, thus promoting the optimization and upgrading of the existing industrial structure of host countries. On the one hand, if Chinese enterprises' outward investment focuses on high value-added service industries, such as developed countries with a strong economic foundation and advanced technological innovation level, Chinese investors will gradually start communication and exchange with technological research and development personnel of the host country, and accelerate the transformation and upgrading of the industries in which they invest in the host country through continuous collaboration. In other words, the investment of Chinese enterprises in host countries with significant technological advantages can help to further optimize the industrial structure of the country or region, thus alleviating the degree of pollution per unit of local output value and improving environmental quality. Second, if Chinese enterprises' outward investment is mainly directed to high-emission industries with resource and market advantages, it will accelerate the damage of domestic energy and resources, which will aggravate the environmental pressure and increase carbon dioxide emissions. Therefore, the industrial heterogeneity of Chinese OFDI entry can lead to the evolution of the host country's industrial structure. Data from the Statistical Bulletin of China's Outward FDI shows that Chinese enterprises mainly favor investment in service industries such as wholesale and retail trade, leasing and commercial services, but the proportion of traditional secondary industries such as manufacturing and mining is also relatively high, so there is uncertainty

about the impact of the industrial structure effect of China's outward FDI on CO2 emissions. Many studies have shown that China does not have a specialization advantage in the production of polluting products, and industrial products at the expense of the environment have long since ceased to be an advantageous export product for China. Therefore, we initially believe that Chinese investment can reduce GHG emissions by accelerating the pace of industrial structure transformation in host countries. Based on the above analysis, this paper puts forward the research hypothesis:

Hypothesis 3: China's outward investment will inhibit carbon emissions in countries along the Belt and Road through structural effects.

4. Empirical Analysis

4.1. Model Construction

The 49 countries that signed the “Belt and Road” agreement with China earlier are selected as the research object, with 2013 as the node, and the sample sizes of the first 10 years and the last 10 years are selected, totaling 20 years of data, to study the impact of China's OFDI on carbon emissions of the countries along the “Belt and Road”. The specific model is as follows:

$$lnCO2 = \alpha 0 + \alpha 1 lnofdi_{it} + \alpha 2 lnstru_{it} + \alpha 3 ee_{it} + \alpha 4 tra_{it} + \alpha 5 des_{it} + \alpha 6 lab_{it} + \alpha 7 city_{it} + \alpha 8 lnpgdp_{it} + \lambda_t + \eta_i + \nu_{it} \quad (22)$$

Where, the explanatory variable is carbon dioxide emissions: CO2, the core explanatory variable is China's outward direct investment, denoted by ofdi, and the control variables are industrial structure stru, energy efficiency ee, foreign trade as a share of GDP tra, population density des, labor force lab, per capita GDP pgdp. i denotes the country, t denotes the time, and λt denotes the time. fixed effects, α denotes coefficients, η_i denotes individual fixed effects, ν_it denotes random error term, and standard errors are heteroskedasticity-robust standard errors. In order to strip out the effects of factors other than OFDI on carbon emissions and to ensure the significance of each explanatory variable, a stepwise regression is used. The time horizon of the study is 2003-2022, and the descriptive statistics of the variables are shown in Table 1.

4.2. Sample Selection and Data Description

Explained variable: carbon dioxide emissions (CO2). Data on CO2 emissions by country are available from a variety of sources, including the World Bank, the International Energy Agency (IEA), the BP World Energy Statistics Yearbook (WESY) published annually by the British Petroleum Corporation (BP), and the U.S. Energy Information Administration (EIA). In view of the fact that the World Bank's data on CO2 emissions are only updated to 2020, the IEA's data for some countries are seriously missing, the BP World Statistical Yearbook does not include some countries and lacks some relevant control variables needed for this paper, this paper chooses the CO2 emissions of the world's countries from the U.S. Energy Information Administration, and the data are all updated to 2022.

Core explanatory variable: China's outward foreign direct investment (OFDI). China's Ministry of Commerce (MOFCOM) updates the Statistical Bulletin on China's Outward Foreign Direct Investment (OFDI) year by year, and this paper selects the data of China's outward foreign direct investment (OFDI) from 2003 to 2022 by updating the Statistical Bulletin on China's Outward Foreign Direct Investment (OFDI) year by year. In view of the Ministry of Commerce of China's OFDI is divided into flow and stock, and the relevant data in this paper exist in the form of stock, so this paper adopts the form of stock to measure China's OFDI.

Control variables. Industrial structure upgrading (stru), the ratio of the value added of the tertiary industry to

the value added of the secondary industry as a proxy variable, the tertiary industry is characterized by high value-added and low pollution, so the carbon emissions can be put into this. Energy efficiency (ee), the improvement of energy efficiency can reduce carbon emissions by reducing the use of fossil fuels and so on, mainly selected the proportion of sustainable energy in the total energy consumption to measure. Trade openness (tra), trade between countries can affect a country's productivity and have an impact on carbon emissions, but also directly reflect whether there is a transfer of carbon transfer and other pollution transfer, the indicator is selected as the proportion of countries' trade volume to GDP (total trade in goods and services / GDP). Population density (des), a large number of academic studies show that the population and carbon emissions have a positive effect, the indicator as long as the number of people per 100 square kilometers of land area of each country to express. Labor force (lab), the labor force makes the core of a country's production and operation, which can stimulate carbon dioxide emissions. Therefore, the total labor force of a country is used as a proxy variable for the indicator. Urbanization (city), the evolution of urbanization consumes a large amount of energy, and can have an impact on CO2 emissions by aggregating population and labor. This indicator is mainly measured using a country's urbanized population.

By the end of 2022, 152 countries will have signed the Belt and Road Initiative with China. In view of the different timeframes for joining the Belt and Road Initiative and the availability of data, this paper selects a representative sample of 49 countries. According to the World Bank's income classification standard, they are divided into high-income countries, middle-income countries and low-income countries. The data were obtained from the China Outward FDI Bulletin, the U.S. Energy Information Administration, the International Energy Agency, and the World Bank database. Descriptive statistics for the sample size required for this paper are shown in Table 1.

Table 1. Main variables and their descriptive statistics.

variant	sample size	average value	standard deviation	minimum value	maximum values
$lnCO_2$	980	3.735	1.628	.459	7.521
lnstru	980	.665	.526	-1.117	2.172
tra	980	108.425	84.277	24.65	834.283
lnee	980	2.371	1.324	0	4.517
des	980	2.978	10.305	.016	80.876
lab	980	1.187	1.688	.017	7.886
city	980	1.552	2.199	.026	10.858
lnpgdp	980	8.749	1.277	.082	11.63

4.3. Benchmark Regression Results

In this chapter, we mainly study the impact of China's OFDI on the actual carbon emissions of the countries along the Belt and Road, specifically, this paper draws on the stepwise regression method adopted by Wang Tao et al. (2022), and puts in the core explanatory variables and control variables in turn for testing to analyze the impact of OFDI on carbon emissions in the countries along the Belt and Road, while controlling for cross-section and time. The empirical results are shown in Table 2. Column (1) in the table is the core control variable, i.e., the impact of OFDI on carbon emissions, and columns (2) to (8) list the empirical results after adding the control variables step by step.

Table 2. Benchmark regression results.

	(1) lnCO2	(2) lnCO2	(3) lnCO2	(4) lnCO2	(5) lnCO2	(6) lnCO2	(7) lnCO2	(8) lnCO2
lnofdi	0.020***	0.020***	0.018***	0.020***	0.018***	0.017***	0.016***	0.015***
	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
lnstru			-0.116***	-0.128***	-0.129***	-0.102***	-0.110***	-0.092***

			(0.032)	(0.032)	(0.031)	(0.029)	(0.029)	(0.029)
lnee			-0.394***	-0.432***	-0.436***	-0.369***	-0.360***	-0.343***
			(0.028)	(0.028)	(0.028)	(0.026)	(0.026)	(0.027)
tra				0.001***	0.001***	0.001***	0.001***	0.001***
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
des					0.038***	0.039***	0.040***	0.041***
					(0.006)	(0.005)	(0.005)	(0.005)
lab						0.387***	0.145**	0.116*
						(0.034)	(0.066)	(0.067)
city							0.205***	0.228***
							(0.048)	(0.049)
lnpgdp								0.106***
								(0.036)
_cons	3.470***	3.470***	4.453***	4.405***	4.317***	3.768***	3.728***	2.770***
	(0.048)	(0.048)	(0.080)	(0.079)	(0.078)	(0.088)	(0.088)	(0.332)
N	980	980	980	980	980	980	980	980
r2	0.126	0.126	0.291	0.321	0.353	0.433	0.444	0.449

*Note: ***, **, and * indicate significant at 1%, 5%, and 10% significance levels, respectively; values in parentheses () are s-statistical errors. Same below.*

From the empirical results, it can be seen that the impact coefficient of OFDI on carbon emissions of countries along the Belt and Road is significantly positive, and the impact coefficient is still significantly positive after adding control variables step by step, which confirms that OFDI has a positive effect on carbon emissions of countries along the Belt and Road. The effect of OFDI on carbon emissions in countries along the "Belt and Road" is confirmed. From the last column, the R2 is 0.449, the fitting degree is passed, and it is positively significant at 1% level, which indicates that OFDI does not effectively mitigate the carbon emissions of the countries along the Belt and Road, which may be related to the location destinations chosen by OFDI when investing in the countries along the Belt and Road, and it may also be attributed to the positive effect of OFDI on carbon emissions. This may be related to the location destinations and industry characteristics of OFDI investments in countries along the Belt and Road. Specifically, OFDI flows more to developing countries along the "Belt and Road", which have a lower level of economic development and backward clean carbon emission technology, and the flow of OFDI to these countries, on the one hand, can drive the development of the local economy and expand the scale of the economy, and in the initial stage of economic expansion, the infrastructure and clean technology cannot be updated and upgraded in time, which will lead to the development of the local economy and the development of the local economy. Secondly, through the outward investment bulletins published by the Ministry of Commerce of China in the past years, it can be seen that OFDI investment industries mainly flowed to the leasing and commercial service industry, mining industry, financial industry, and wholesale and retail trade, etc. Although the investment of Chinese enterprises has gradually shifted to the service industry, the traditional manufacturing industry and the mining industry are still the main industries of investment, especially in the "One Belt, One Road". "This is not conducive to the realization of the host country's "dual-carbon" goal, despite the gradual shift of Chinese enterprises' investment to the service sector. This indicates that OFDI investment in countries along the "Belt and Road" is more focused on improving local productivity, and not enough investment in clean, low-carbon and environmentally friendly technologies.

In addition, from the empirical results, it can be seen that the improvement of energy efficiency and the adjustment of industrial structure can effectively reduce the carbon emissions of the countries along the "Belt and Road". The improvement of energy efficiency indicates that the proportion of renewable energy and other clean energy sources in a country's total energy consumption is getting higher and higher, replacing more and more fossil energy and other consumption, so that the carbon emissions from traditional fossil fuels and other energy sources are effectively reduced. On the other hand, under the effective promotion of the United Nations and the International Energy Agency, more and more countries are not only launching their own energy substitution programs, but also formulating more and more stringent trade policies for their own cleaner products, which leads to more and more countries taking the initiative to produce cleaner products, thus reducing their own carbon emissions. The

significant negative impact of industrial structure adjustment on carbon emissions is mainly due to the fact that the tertiary industry has different characteristics from the secondary industry, and the tertiary industry is more high value-added and low-polluting, so the optimization of the industrial structure contributes to the decline of a country's carbon emission structure. Correspondingly, the increase of population, the expansion of population density, economic development, and the increase of urban population will lead to the rise of carbon emissions, mainly because these factors have prompted enterprises to expand production and lead to the increase of carbon emissions. The increase in population and the evolution of urbanization will lead to the use of fossil fuels that are cheaper at this stage thus increasing carbon emissions. An increase in the labor force and rapid economic growth will also lead to an expansion of production, which will lead to an increase in the use of fossil fuels and an increase in carbon emissions. Bilateral trade will also increase carbon emissions, thus proving the existence of the current carbon shifting effect.

4.4. Endogeneity test

The endogeneity problem of the possible causal relationship between OFDI and carbon emissions, in order to alleviate this problem, this paper draws on the practice of Chen Zhizhi et al. (2024), and utilizes the data of China's OFDI in the first period after and the lagged two periods as the instrumental variables to conduct the endogeneity test. The specific results are shown in Table 3, and the results show that the impact of China's OFDI on carbon emissions in countries along the Belt and Road is significantly positive, and the test results are consistent with the results of the benchmark regression.

Table 3. Endogeneity test.

	(1) lnCO2	(2) lnCO2
lnofdi	0.031***	0.050***
	(0.008)	(0.114)
lnstru	-0.091***	-0.095***
	(0.029)	(0.03)
tra	0.0001	-0.0003
	(0.1861)	(-0.8090)
des	0.003***	0.003***
	(0.0001)	(0.0001)
lab	0.000	0.000
	(1.506)	(1.608)
lnee	-0.323***	-0.328***
	(0.027)	(0.029)
lnpdgp	0.172***	0.181***
	(0.037)	(0.039)
city	0.001***	0.001***
	(0.0001)	(0.0001)
r2_a	0.3793	0.3307
N	980	980

4.5. robustness check

4.5.1. Replacing the core explanatory variables

In this paper, we refer to Dong Kangyin et al. (2023), who change the core explanatory variable from OFDI stock to per capita OFDI stock,and the regression results are plotted as shown in Table 4. Obviously, the per capita OFDI

stock replacing OFDI is positive and significant at 1% coefficient, industrial restructuring and energy efficiency improvement have obvious inhibition on carbon emission, while international trade, population growth, urbanization evolution and economic growth all have positive effects, and the main effect is consistent with the significance of control variables. The main effect is consistent with the significance of the control variables, indicating that the main regression results are reliable. At the same time, it can also be concluded that OFDI can indeed adjust the industrial structure and improve the energy efficiency of the countries along the "Belt and Road", but the economic and population growth will also increase carbon emissions, so it reveals that the Chinese government should be guided by the green "Belt and Road" plan and cooperate with the Chinese government in the green "Belt and Road" plan, so that the Chinese government should be guided by the green "Belt and Road" plan. Therefore, it reveals that the Chinese government should, under the guidance of the green "Belt and Road" plan and in line with the carbon emission reduction policies issued by each country, guide OFDI to rationally integrate the investment scope of outward investment enterprises, actively promote the greening of initiatives, and strive to ensure a win-win situation for energy conservation and emission reduction, as well as economic growth (Table 4).

Table 4. Robustness test effects of replacing the core explanatory variable with OFDI per capita.

	(1) lnCO2
lnpofdi	0.126**
	(0.052)
lnstru1	-1.223***
	(0.291)
lnee	-0.376***
	(0.028)
tra	0.120***
	(0.018)
des	4.177***
	(0.657)
lab	15.064**
	(6.678)
city	2.008***
	(0.490)
lnpgdp	-0.067*
	(0.039)
_cons	3.930***
	(0.093)
N	980
r2	0.444

4.5.2. Removing abnormal years

Given that the world economic development in 2020-2022 is in trouble because of the impact of objective factors, and the flow of resources has come to a standstill on a global scale, this paper chooses to remove the samples of the 2020-2022 years, and examines the sample regression of the 2003-2019 years for re-measurement, and the regression results are shown in Table 5. It can be seen that after removing the epidemic years, the main effect is still positive and significant at a coefficient of 1%, and the significance of each control variable is basically the same compared to the main regression, which withstands the test after removing the epidemic years, so the main regression empirical results are credible.

Table 5. Effect of Robustness Tests to Exclude Abnormal Years.

	lnCO2
lnofdi	0.023***
	(0.006)
lnstru	-0.096***
	(0.032)
lnee	-0.352***
	(0.030)
tra	0.001***
	(0.000)
des	0.040***
	(0.006)
lab	0.165**
	(0.077)
city	0.222***
	(0.058)
lnpgdp	0.021
_cons	3.428***
	(0.199)
N	833
r2	0.452

4.6. Heterogeneity analysis

The research objects selected in this paper are all countries along the "Belt and Road", but given that the "Belt and Road" initiative was put forward in 2013 and the development level of each country is not consistent, based on the results of the baseline regression, this chapter analyzes the impact of OFDI on the carbon emissions of the countries along the "Belt and Road" in three mechanisms: policy differences and development differences. Therefore, based on the results of the benchmark regression, this chapter analyzes the heterogeneity of OFDI on carbon emissions in countries along the "Belt and Road" in terms of three mechanisms: policy heterogeneity and development heterogeneity.

4.6.1. Policy Heterogeneity

The "Belt and Road" initiative was proposed by China in 2013, and its core connotation is to adhere to the principle of "common business, common construction and sharing", promote infrastructure construction and connectivity, strengthen economic policy coordination and development strategy docking, promote coordinated and linked development, realize common prosperity, and jointly build a community of shared destiny for mankind. Under the guidance of the principle of "common business, common construction and sharing", the countries along the Belt and Road will promote policy communication, facility connectivity, trade connectivity, capital integration and people-to-people communication, so as to jointly build a community of interests with mutual political trust, economic integration and cultural tolerance, We will work together to build a community of interests, responsibility and destiny based on mutual political trust, economic integration and cultural tolerance. The green Belt and Road construction is guided by the concepts of ecological civilization and green development, adhering to the principles of resource conservation and environmental friendliness, upgrading the greening of policy communication, facility connectivity, trade facilitation, capital integration and people-to-people communication, and integrating ecological protection into all aspects and aspects of the Belt and Road construction. The greening level of policy communication, facility communication, trade communication, financial communication and people-to-people communication should be improved, and ecological protection should be integrated into all aspects and the whole

process of the construction of the "Belt and Road", so that the fruits of green development will benefit the people of all countries. Referring to the study of Chang Dunhu et al. (2023), taking the "Belt and Road" initiative as a node, divided into two periods, 2003-2013 and 2014-2022, we explore whether the "Belt and Road" initiative has a significant impact on OFDI on the "Belt and Road" construction, and whether the "Belt and Road" initiative has a significant impact on the "Belt and Road" construction. countries along the "Belt and Road" has an impact on carbon emissions. The regression results are shown in Table 6.

Table 6. Policy Heterogeneity.

	lnCO2	lnCO2
	2003-2013	2014-2022
lnofdi	0.026***	-0.020***
	(-0.006)	(-0.007)
lnstru	-0.086**	-0.111***
	(-0.035)	(-0.027)
lnee	-0.362***	-0.281***
	(-0.042)	(-0.032)
tra	0.002***	-0.001
	(0.000)	(-0.004)
des	0.038***	0.030**
	(-0.007)	(-0.015)
lab	0.046	-0.016
	(-0.098)	(-0.08)
city	0.290***	0.184***
	(-0.086)	(-0.056)
lnpgdp	-0.039	0.165***
	(-0.039)	(-0.046)
N	539	441
r2	0.41	0.409

From the empirical results, it can be seen that before the Belt and Road Initiative was proposed, OFDI investment in countries along the Belt and Road had a significant positive effect on carbon emissions, which may be due to the fact that before the Belt and Road Initiative, especially the Green Belt and Road Plan, OFDI focused more on increasing the productivity of capital inflow countries, while national trade also shifted carbon emissions by pollution. Before the "Belt and Road" initiative, especially the Green Belt and Road Plan, OFDI focused more on increasing the productivity of the inflowing countries, while national trade also shifted the carbon emissions, but after 2014, the pollution shifting brought by international trade disappeared, and the industrial structure upgrading brought by OFDI became more obvious, which lowered the carbon emissions of the inflowing countries. Population increase and urbanization still significantly increase carbon emissions, which may be related to the fact that OFDI flows more into countries with lower levels of economic development, where the population tends to prefer inexpensive fossil fuels. Therefore, we can conclude that after the "Belt and Road" initiative, OFDI significantly reduces carbon emissions by upgrading industrial structure and improving energy efficiency, and does not bring pollution transfer and pollution halo, so countries along the "Belt and Road" should be more active in introducing OFDI for investment. Therefore, countries along the "Belt and Road" should more actively introduce OFDI for investment, and realize low-carbon green development on the basis of upgrading economic scale.

4.6.2. Development Heterogeneity

The World Bank publishes an annual indicator of high-income countries, measured in terms of gdp per capita. The international theory of the middle-income trap holds that when a country's per capita income reaches the

middle level, it is unable to successfully realize the transformation of its economic development mode due to the contradictions in the original development mode that have accumulated for a long time, resulting in insufficient impetus for economic growth, and ultimately a state of economic stagnation, which prevents it from entering the ranks of high-income countries. It is characterized by: insufficient strength of economic growth and high risk of stalling; rapid widening of the income distribution gap; serious imbalance in financial development and huge risk of financial regulation; overall insufficiency of public services and huge gap between urban and rural areas and regions; inertial dependence on low-cost exuberant development mode, and great difficulty in structural adjustment. Therefore, referring to Liu Chao et al. (2023), the heterogeneity analysis is conducted according to the high-income national standards published by the World Bank in 2022, mainly to explore the effect of the level of economic development on carbon emissions. The regression results are shown in Table 7.

Table 7. Development mechanism.

	lnCO2 pgdp<13250	lnCO2 pgdp>13250
lnofdi	0.026***	-0.002
	(0.008)	(0.007)
lnstru	-0.090**	0.091*
	(0.035)	-0.05
lnee	-0.394***	-0.246***
	(0.037)	(0.039)
tra	0.002***	0.001
	(0.001)	(-0.001)
des	0.291***	0.040***
	(0.046)	(0.005)
lab	-0.068	1.865***
	(0.072)	(0.258)
city	0.299***	-0.891***
	(0.053)	(0.196)
lnpgdp	0.202***	-0.642***
	(0.042)	(0.117)
_cons	1.999***	10.186***
	(0.372)	(1.216)
N	677	441
r2	0.530	0.409

According to the empirical results, OFDI has not been able to significantly inhibit carbon emissions when the national standard of high income has not been reached, although industrial restructuring and energy efficiency improvement still have significant inhibition to reduce carbon emissions, but international trade brings pollution transfer, population expansion, urbanization and large-scale construction still raise carbon emissions, therefore, for countries that still have not crossed the middle-income trap, it is important to focus on improving the efficiency of utilizing OFDI and allocating resources well. Finally, economic growth has also further pushed up carbon emissions, so for countries that have not yet crossed the middle-income trap, it is important to focus on improving the efficiency of OFDI utilization and good resource allocation. On the other hand, when the middle-income trap is crossed and high-income countries are reached, the positive and significant effect of OFDI on carbon emissions disappears, which indicates that when OFDI is utilized to promote economic growth and the middle-income trap is crossed, the intensity of carbon dioxide emissions of the country will be curbed, so as to realize the goal of "dual-carbon" development. On the contrary, the adjustment of industrial structure will be positively significant to carbon emission, which may be due to the fact that the perfect industrial structure itself is the characteristic of cross-border middle-income trap to reach the high-income countries, so the high-income countries themselves have a perfect

industrial structure, their tertiary industries are very developed, the secondary industry is transferred to the developing countries through multinational corporations, and the domestic secondary industry pollutes less, and on the other hand, the domestic infrastructure is older and most of them have reached the level of "double-carbon" development goal. On the other hand, their domestic infrastructures are older and most of them have reached the critical point of renewal. The current trend of globalization has suffered a setback, and developed countries are pointing out higher welfare levels and higher levels of unemployment, so developed countries are also carrying out the policy of returning manufacturing industries. Therefore, when OFDI enters these industries, relative to countries with lower economic levels, the same injection of capital into the secondary industry has a greater impact on carbon dioxide emissions, and by the same token, an increase in the labor force in developed countries will also increase carbon emissions to a certain extent. Energy use efficiency, economic development, and urbanization in high-income countries have a significant inhibitory effect on carbon emissions.

4.7. further analysis

From the above analysis, it can be seen that OFDI will have a positive effect on the total carbon emissions of the countries along the Belt and Road, but its effect on carbon intensity has not received much attention. Carbon intensity is usually measured by carbon emissions per unit of output value, reflecting the causal relationship between a country's economic level and the greenhouse effect. If a country or region produces significantly lower carbon emissions per unit of GDP during rapid economic development, it indicates that the country's economic development is in a low-carbon mode. Therefore, on the basis of the previous paper, this paper replaces the explanatory variable with carbon emission intensity (EE) for stepwise regression, and studies and analyzes the potential impact of China's outward foreign direct investment on carbon emission intensity. The empirical results are shown in Table 8.

Table 8. Impact of China's outward foreign direct investment on carbon intensity in countries along the Belt and Road.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnofdi1	-0.163***	-0.167***	-0.148***	-0.148***	-0.148***	-0.147***	-0.143***	-0.135***
	(0.030)	(0.030)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.028)
lnstru1		-0.293***	-0.305***	-0.303***	-0.304***	-0.334***	-0.316***	-0.253***
		(0.092)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.088)
lnee			0.063***	0.062***	0.063***	0.056***	0.055***	0.049***
			(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
tra				0.004	0.002	0.001	-0.003	-0.004
				(0.010)	(0.011)	(0.011)	(0.011)	(0.011)
des					-0.152	-0.169	-0.219	-0.796***
					(0.170)	(0.169)	(0.169)	(0.194)
lab						-3.872***	2.292	1.147
						(1.045)	(2.033)	(2.008)
city							-0.526***	-0.412***
							(0.149)	(0.148)
lnpgdp								0.067***
								(0.012)
_cons	0.628***	0.644***	0.499***	0.497***	0.502***	0.559***	0.574***	0.521***
	(0.008)	(0.010)	(0.020)	(0.021)	(0.022)	(0.027)	(0.027)	(0.028)
N	980	980	980	980	980	980	980	980
r2	0.172	0.181	0.237	0.237	0.237	0.249	0.259	0.286

In terms of the overall goodness of fit, with the gradual introduction of explanatory variables, the R^2 of the

model improves from 0.172 to 0.286, and the adjusted R^2 also rises from 0.109 to 0.226. The F-statistic is significant in all the models, which indicates that the regression equation is statistically significant in a good way. Outward foreign direct investment (lnofdi), as the core explanatory variable, shows a significant negative impact in all eight models, with coefficients stabilized between -0.163 and -0.135 and significant at the 1% significance level. This result strongly supports the hypothesis that China's OFDI contributes to the reduction of domestic carbon intensity. This may be due to the fact that OFDI promotes industrial upgrading and technological progress, realizes the transfer of some high-carbon industries through outward investment, and the international technology spillover effect brought by outward investment enhances the production efficiency. Introduced from column (2), there is always a significant negative effect, with coefficients fluctuating from -0.253 to -0.334 and significant at 1% level, which indicates that China's outward investment helps to reduce carbon intensity through the optimization of industrial structure. Energy efficiency (lnee) shows a stable positive impact (coefficient about 0.049-0.063) and is significant at the 1% level. This may reflect a rebound effect in the process of energy use efficiency improvement. Technological progress (tra) does not show statistical significance although the coefficient is negative, which may indicate that the effect of technological progress on carbon intensity needs to be visible in the longer term. Other important control variables: development level (des), significantly negative (-0.796) in the final model, indicating that higher development levels help reduce carbon intensity; urbanization level (city): significantly negative (-0.412), indicating that the urbanization process helps reduce carbon intensity; GDP per capita (pgdp2): significantly positive (0.067), indicating that economic growth may bring about an increase in carbon intensity.

The conclusion shows that with the proposal of China's “Belt and Road” initiative, China's investment in the countries related to the “Belt and Road” continues to rise, but also to a certain extent contributes to the rise in the total amount of carbon emissions of the relevant countries, according to the consistency analysis can be concluded, these are According to the consistency analysis, it can be concluded that these are the stage-by-stage results brought about by most of the low- and middle-income countries in the “Belt and Road” on the basis of utilizing China's outward investment to develop their economic scale. The results in this chapter also lay the foundation for the decomposition of carbon emission effects in the next chapter.

5. Mechanism testing

Chapter 4 mainly analyzes the impact of OFDI on carbon emissions of the “Belt and Road”, and concludes that OFDI has no significant inhibiting effect on carbon emissions of the countries along the “Belt and Road”, but the mechanism of the impact is not analyzed in depth. In this chapter, drawing on the model of the effect of foreign investment on carbon emissions used by Cao Xiang et al. (2024), we decompose the impact mechanism of OFDI on carbon emissions in countries along the Belt and Road into the scale effect, technology effect, and structural effect, so as to analyze the impact of OFDI on carbon emissions in countries along the Belt and Road in depth. Road” on carbon emissions in countries along the Belt and Road, so as to deeply analyze the intrinsic influence mechanism of OFDI on carbon emissions in countries along the Belt and Road.

5.1. Model Construction

From the theoretical derivation in Chapter 2, it can be seen that the impact of OFDI on carbon emissions of countries along the “Belt and Road” is not direct, but indirect through the scale effect, structural effect, and technological effect, and it is possible to study the relationship between OFDI and carbon emissions of countries along the “Belt and Road” by setting up a system of joint equations. By establishing a system of joint equations to study the impact between OFDI and carbon emissions of countries along the “Belt and Road”, it can be seen from equation (17):

$$CO_2 = Scale * Stru * Tech \tag{22}$$

Where, CO2 type carbon emissions, Scale type scale effect, Stru is the structural effect, Tech is the base effect, take the logarithm of its two sides have:

$$lnCO_2 = lnScale + lnStru + lnTech \tag{23}$$

The carbon emissions of the countries along the “Belt and Road” can be decomposed into three major effects: scale, structure, and technology. Given that this chapter investigates the mechanism of China's outward foreign direct investment (OFDI) on the carbon emissions of the countries along the “Belt and Road”, it is important to incorporate the three effects into the set of linked equations. In view of this chapter's study of the effect of Chinese OFDI on carbon emissions in the countries along the “Belt and Road”, we will incorporate Chinese OFDI into the three kinds of effects to establish a system of joint equations:

$$lnCO_{2_{it}} = \alpha 1 lnScale_{it} + \alpha 2 lnStru_{it} + \alpha 3 lnTech_{it} \tag{24}$$

$$lnScale_{it} = \beta 1 lnOFDI_{it} + \beta 2 des_{it} + \beta 3 tra_{it} + \beta 4 city_{it} + \epsilon_{it} \tag{25}$$

$$lnStru_{it} = \gamma 1 lnOFDI_{it} + \gamma 2 pgdp_{it} + \gamma 3 tra_{it} + \gamma 4 city_{it} + \epsilon_{it} \tag{26}$$

$$lnTech_{it} = \eta 1 lnOFDI_{it} + \eta 2 pgdp_{it} + \eta 3 tra_{it} + \eta 4 lab_{it} + \eta 5 city_{it} + \epsilon_{it} \tag{27}$$

Equation (24) represents the total effect of China's OFDI on carbon emissions in the countries along the Belt and Road. Equation (25) represents the scale effect of China's OFDI on countries along the Belt and Road, with the introduction of control variables such as population density, trade openness and urban population. Equation (26) represents the structural effect of China's OFDI on carbon emissions in the countries along the Belt and Road, with the introduction of control variables such as GDP per capita, trade openness and urban population. Equation (27) represents the technological effect of China's OFDI on carbon emissions in the countries along the Belt and Road, and introduces control variables such as GDP per capita, trade openness, labor force population and urban population.

Therefore, this chapter decomposes the carbon emission of China's OFDI on the countries along the “Belt and Road” into scale effect, technical effect and structural effect.

5.2. Variable selection

This chapter measures and analyzes the scale, technological and structural effects of OFDI on carbon emissions based on a sample of 49 countries along the “Belt and Road” from 2003 to 2022, while other countries are not included in the analysis due to the fact that they joined the “Belt and Road” at a later time or the sample is indeed very small. In view of the fact that other countries joined the “Belt and Road” at a later time, or the sample is not included in the analysis. The sample data are mainly from the China Outward Investment Bulletin, BP World Energy Statistics, International Energy Agency, World Bank, and U.S. Information and Energy Agency. The variables are measured as follows:

1. Carbon dioxide emissions (CO2). The carbon emission data of each country measured in the U.S. Energy Agency is chosen as the explanatory variable for regression.

2. China's outward investment (OFDI): The stock of outward investment in the “China Outward Investment Bulletin” is chosen as an indicator of OFDI, and the larger the scale of China's outward investment, the greater the production capacity of the inflow country, and the economic scale and degree of development are also increased, so that China's outward foreign direct investment (OFDI) and carbon emissions of the countries along the Belt and

Road are measured in Equation 23. “Therefore, in Equation 23, the scale effect Scale of China's OFDI and the carbon emissions of the countries along the Belt and Road is proposed to be positively correlated, in which the scale effect Scale is measured by the total domestic production (constant value dollars in 2015).

The process of China's outward FDI to the countries along the “Belt and Road” is also a process of technology diffusion, especially after China proposes the construction of the green “Belt and Road”, China's outward FDI will also enhance the related countries' technology level through technology spillover. Technology level. In addition, China's investment in solar energy and water resources in the countries along the Belt and Road can also reduce the use of fossil fuels in the relevant countries, therefore, the technological effect of China's OFDI and the countries along the Belt and Road is not only the same as the technological effect, but also the structural effect of China's OFDI. Therefore, China's OFDI is negatively correlated with the technological effect and the structural effect of the countries along the Belt and Road. Among them, the technological effect of the countries along the Belt and Road, Tech, is measured by the energy efficiency of each country, and the structural effect of the countries along the Belt and Road, Stru, is measured by the ratio of the value added of the tertiary industry to the value added of the secondary industry.

3. Control variables. This chapter mainly introduces the variables of population density (des), city population (city), labor force population (lab), per capita gross domestic product (pgdp), and trade openness (tra). Among them, population density (des) is measured by the number of people per kilometer of land area in each country, trade openness (tra) is selected to be expressed as the ratio of trade to GDP in each country, city population (city) is expressed by the population of towns and cities, economic growth (pgdp) is selected to be measured by GDP per capita in constant 2015 dollars, and labor input (lab) is selected to be measured by the the total labor force of each country as the measure.

5.3. Mechanism results testing and analysis

5.3.1. Scale effect

The regression results of the scale effect of China's OFDI on the carbon emissions of the countries along the Belt and Road are shown in Table 9, which shows that the scale effect of China's OFDI on the countries along the Belt and Road is positive and significant at the level of 1%, indicating that It can be seen that the scale effect of Chinese OFDI on the countries along the “Belt and Road” is positive and significant at the 1% level, indicating that China's OFDI has significantly increased the economic aggregates of the countries along the “Belt and Road”, which is consistent with the relevant domestic studies. The inflow of China's OFDI into the countries along the “Belt and Road” has provided sufficient funds, especially for the low- and middle-income countries, which undoubtedly alleviates the problem of insufficient funds and constrains their economic development, so that their national economic development plans can be successfully implemented; second, China's OFDI will also bring relevant technologies and technologies to the countries along the “Belt and Road”, which is consistent with the relevant domestic studies. Secondly, China's OFDI will also bring relevant technologies to enhance the production capacity of the relevant countries, extend the industrial chain, enhance the value-added, so as to make their domestic economic development more rapidly; finally, the relevant countries due to unemployment and other problems lead to domestic political instability, unable to focus on economic development, and China's OFDI's sustained and stable inflow can be a stable, long-term solution to the domestic economic problems, to ensure the sustainability of the domestic economic development. Sustainability. Therefore, from a comprehensive point of view, China's OFDI significantly increases the economic scale of the countries related to the Belt and Road, which is also consistent with the positive correlation between China's OFDI and scale in this chapter.

Table 9. Scale effects.

	(1) lnScale
lnofdi	0.015***
	(0.004)
tra	-0.001***
	(0.000)
des	-0.005
	(0.004)
city	-0.002
_cons	8.485***
	(0.044)
N	980
r2	0.536

5.3.2. Technological effect

The regression results of the technological effect of China's OFDI on the countries along the "Belt and Road" are shown in Table 10, which is positive and significant at the 1% level, indicating that China's OFDI will improve the technological level of the inflow countries, and the use of fossil fuels will be further reduced. In the process of China's OFDI, on the one hand, it can enter the field of clean energy, increase the amount of clean energy extraction, and reduce the amount of fossil fuel extraction and use; on the other hand, when China invests in the countries along the "Belt and Road", it can either acquire local R&D institutions through multinational corporations or set up R&D centers, and cooperate with local universities and colleges. On the other hand, when China invests in countries along the "Belt and Road", it can either acquire local R&D institutions or set up R&D centers directly in the form of multinational corporations, or cooperate with local universities and colleges to improve the local technological level. In addition, the evolution of economic growth and urbanization significantly inhibits technological progress, while international trade significantly promotes technological progress, which may be due to the fact that for a significant portion of low-income and middle-income countries, population growth and large-scale influx of cities dilute the fruits of technological progress, while international trade may benefit from the fact that more and more countries have introduced environmental regulatory policies, and have begun a more stringent audit of polluting products in international trade. international trade may have benefited from the introduction of environmental regulatory policies in a growing number of countries, which have begun to scrutinize polluting products in international trade more closely. Urbanization is often driven by large amounts of capital and energy, which can undermine the availability of funds for clean technology research and development.

Table 10. Technical effects.

	(1) lnee
lnofdi	0.0188***
	(2.8566)
lnpgdp	-0.4308***
	(-8.1836)
city	-0.026***
	(-3.9667)
tra	0.0012***
	(5.5548)
_cons	6.0103***
	(13.4172)
N	980
r2	0.2025

5.3.3. Structural effects

The structural effect of China's OFDI is shown in Table 11, which shows that China's OFDI has a significant negative effect on the industrial structure of the countries into which the investment capital flows, indicating that China's OFDI cannot effectively promote the transfer of industries from high-pollution industries to high-value-added and low-pollution services in countries along the Belt and Road, which is related to the characteristics of the industries in which China's OFDI is made. This is related to the industry characteristics of China's outward investment. In order to promote the growth of economic scale as soon as possible, a considerable part of the countries along the "Belt and Road" will also attract large-scale capital in the industrial industry which has faster threshold and capital return, and higher profit margins, which is better reflected by the "China's Outward Investment Bulletin" in the past years. However, it is foreseeable that with the expansion of China's "Belt and Road" initiative, especially the green "Belt and Road", and the implementation of a series of sustainable development policies, the Chinese government will actively guide the adjustment of the industry distribution of outward investment. Relevant countries along the "Belt and Road" have also introduced their own low-carbon development policies, therefore, as time goes on, China's outward investment will play a positive role in promoting the adjustment of the industrial structure of the relevant countries along the "Belt and Road". On the other hand, economic growth and labor force will also have significant side effects on industrial restructuring, which may be due to China's outward investment in a large number of domestic industrial sectors, the industrial sector has labor-intensive characteristics, increasing employment at the same time will make the ratio of labor force employed in industry and service industry change.

Table 11. Structural effects.

	(1)
	lnstru
lnofdi	-0.002**
	(0.001)
tra1	0.000
	(0.000)
lnpgdp	-0.034**
	(0.017)
lab	-0.056**
	(0.027)
city	0.008
	(0.013)
	(0.150)
N	980
r2	0.116

5.3.4. Total effect

The above content mainly discusses the scale, technological and structural effects of China's OFDI on the countries along the Belt and Road, and China's OFDI will expand the country's economic scale and improve the country's technological level, but there is a significant negative effect on the shift of the industrial structure to low-pollution industries. In the following, we aim to analyze the total effect of China's OFDI on the carbon emissions of the countries along the Belt and Road, and Table 12 describes the regression results of the total effect of China's OFDI on the carbon emissions of the countries along the Belt and Road.

Table 12. Total effects.

	lnCO2
lnstru	-0.078**
	(0.034)
lnee	-0.0359***
	(0.029)
lngdp	0.213***
	(0.051)
_cons	2.646***
	(0.460)
N	980
r2	0.298

From the regression results, it can be seen that from the perspective of scale effect, China's outward FDI has a significant positive effect on the carbon emissions of the countries related to the “Belt and Road”, which is significant at the level of 1%, so it can be concluded that the growth of economic scale is not conducive to the realization of the low-carbon goals of the relevant countries. On the contrary, both technological progress and industrial restructuring have a significant mitigation effect on carbon emissions, which is conducive to the realization of the country's dual-carbon development goals. Specifically, the coefficient of the scale effect on carbon emissions is 0.213, the coefficient of the technological effect is -0.0359, and the coefficient of the industrial structure is -0.078, and the coefficient of the economic scale is larger than the sum of the technological progress and the structural adjustment of the industry while the night, therefore, we can determine that the growth of the economic scale will bring about a significant reduction of carbon emissions in the relevant countries of the “One Belt, One Road”, and will be beneficial to the realization of their dual-carbon development goals. Therefore, we can judge that the positive contribution of economic scale growth to the carbon emissions of the countries related to the “Belt and Road” has greatly weakened the emission reduction effect brought by technological progress and industrial structure adjustment.

6. Conclusions and recommendations

6.1. Main findings

Based on the growing concern of the international community about carbon emissions and the increasing scale of China's outward foreign direct investment (OFDI) under the implementation of China's “Belt and Road” policy, this paper analyzes the impact and mechanism path analysis of China's OFDI on carbon emissions of the countries along the “Belt and Road” in terms of theoretical and empirical analyses, and draws the following conclusions. The impact of China's OFDI on the carbon emissions of the countries along the “Belt and Road” is analyzed from both theoretical and empirical levels, and the following conclusions are drawn.

1. From the theoretical point of view, the mechanism path of China's OFDI on the carbon emissions of the countries along the “Belt and Road” can be decomposed into the scale effect, technology effect, and structural effect;

2. China's OFDI has increased the total carbon emissions of the countries along the Belt and Road, but at the same time significantly reduced the carbon intensity of the countries along the Belt and Road, and in terms of the total amount of carbon emissions alone, the carbon intensity of the countries along the Belt and Road has been significantly reduced since China's exclusion of the “Belt and Road” in 2014, while the carbon intensity of the countries along the Belt and Road has been significantly reduced. “In terms of total carbon emissions, since China's exclusion of the Belt and Road Initiative in 2014, and especially after the green Belt and Road Initiative was put forward, the boosting effect of China's outward FDI on the total carbon emissions of countries along the Belt and

Road has disappeared. The effect of Chinese OFDI on the total carbon emissions of countries along the Belt and Road has disappeared;

3. the increase of China's OFDI on the total carbon emissions of the countries along the Belt and Road is due to the fact that the positive effect of the increase in the scale of the economy outweighs the negative effect of the technological upgrading and structural improvement, which reflects that the countries along the Belt and Road, especially the middle and low-income countries, utilize China's OFDI to promote the development of the economy and the development of the economy. This reflects that countries along the "Belt and Road", especially the relevant low- and middle-income countries, are taking advantage of China's support for.

6.2. Policy recommendations

Based on the above conclusions, policy recommendations are put forward in the following areas:

1. under the "Green Belt and Road" initiative, adjusting the distribution of China's outward investment enterprises, tilting towards low-carbon and green investment industries, reducing investment in construction, fossil fuel extraction and other industries, and giving priority to low-carbonization industries in countries along the "Belt and Road" route enterprises;

2. Help countries along the "Belt and Road" to upgrade their technological level, establish a technological upgrading system through university exchanges and other channels, and strengthen measures to help talents in high-tech industries, so as to help countries along the "Belt and Road" to upgrade their own technological level, and to use low-carbon and green technologies to Replace high-carbon technologies to offset the positive effect of carbon emissions brought about by the expansion of economic scale. Replace high-carbon technologies with low-carbon and green technologies to offset the positive effect of carbon emissions brought about by the expansion of economic scale;

3. guiding different Chinese outward investment enterprises to invest in countries of different economic levels, adjusting the economic structure of the relevant countries, helping them to cross the income trap of middle-developed countries, and realizing the goal of "dual-carbon" at an early date.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

Jinpei Cao: Conceptualization, Methodology, Supervision, Formal analysis, Writing - review & editing. Xudong Hu: Software, Visualization, Funding acquisition, Writing - original draft, Writing - review & editing, Formal analysis. Sen Wang: Conceptualization, Methodology. Pu Hao: Writing - review & editing.

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