Analysis of the Per Capita Carbon Emission Effect of China's OFDI to Countries Along the "Belt and Road"

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Abstract. Under the "Belt and Road" initiative, China adheres to the principle of co-business, construction and sharing, and the exchange and cooperation with countries along the route as well as the economic and trade relations are getting closer and closer, and the OFDI between China and countries along the " Belt and Road" is growing steadily. This paper uses a combination of theoretical research and empirical analysis to study the per capita carbon emission In the theoretical analysis, a theoretical model of carbon emissions and China's OFDI is constructed. In the empirical analysis, firstly, the stock of Chinese OFDI is taken as the core explanatory variable. Then, based on the availability of data, the cross-country data of China's OFDI to 76 countries along the "Belt and Road" from 2009 to 2019 are selected. The relationship between China 's OFDI and carbon emissions was also introduced as control variables. The relationship between China 's OFDI and carbon emissions is analysed empirically through an extended individual time double fixed effects model. The findings of this paper are as follows: (1) the regression coefficient of Chinese direct investment (1) the regression coefficient of Chinese direct investment in the coastal countries is significantly negative, indicating that Chinese OFDI suppresses carbon emissions per capita in the coastal countries; (2) GDP per capita significantly contributes to (2) GDP per capita significantly contributes to the increase of carbon emissions in the coastal countries; (3) the impact of labour force level on carbon (3) the impact of labour force level on carbon dioxide emissions per capita in the coastal countries is significantly negative, i.e. the increase of labour force level can effectively reduce carbon emissions in the coastal countries; (4) The impact of industrial structure on per capita CO2 emissions in the countries along the route is significantly positive. Finally, the policy implications are as follows.

Keywords: OFDI; CO2 Per Capita; "One Belt, One Road"; Extended Double Fixed-effect Model.

1. Introduction

In September and October 2013, General Secretary Xi proposed a major initiative to jointly build the Silk Road Economic Belt and the 21st Century Maritime Silk Road, known as the Belt and Road Initiative.

As economic globalization continues to develop, OFDI has become an important way to participate in the international division of labour. China has ranked among the top three countries in the world in terms of OFDI for ten consecutive years. Since the introduction of the "Belt and Road" initiative, China's OFDI flows to countries along the route have increased from US$12.63 billion in 2013 to US$24.15 billion in 2021, and the share of China's OFDI flows to countries along the "Belt and Road" route in China's total annual OFDI flows has increased from 11.7% in 2013 to 20.5% in 2011. The share of OFDI flows to countries along the Belt and Road in China's total annual OFDI flows has increased from 11.7% in 2013 to 13.5% in 2021. This shows that the "One Belt, One Road" initiative has greatly boosted the development of OFDI in China. However, it is worth noting that OFDI, as an important vehicle for implementing the "going out" strategy (Changhong Pei, 2009[40]; Mengqi Gong and Haiyun Liu, 2020[41]), its impact on the regional ecological environment cannot be ignored (Fei Nie and Haiyun Liu, 2016[42]).

In recent years, the "Belt and Road" initiative has received widespread attention from academics at home and abroad, and research on China's OFDI to countries along the "Belt and Road" has mostly focused on economic growth, location choice, influencing factors, technology spillover and trade

effects. The research on China's OFDI to countries along the "One Belt and One Road" has received widespread attention both at home and abroad[1].

In terms of the impact of Chinese OFDI on the economic growth of countries along the Belt and Road, some scholars have found that OFDI has a positive contribution to the economic growth of host countries (Silk Road Foundation Youth Group, 2022[2]; Naihua Jiang , 2022[4]; Xiumin Niu, 2021[5]; Dossou Toyo Amegnonna Marcel (2022). Dossou Toyo Amegnonna Marcel(2022)[3] shows that Chinese OFDI helps to reduce income inequality in Africa on the one hand, and has a positive and significant impact on welfare levels in Africa on the other.[3]

In terms of location choice of countries along the Belt and Road, studies have been conducted mainly from the perspectives of digital economy, capital cost, institutional distance, green development level, technology level and cultural distance. For example, some scholars have found that by improving the quality of institutions and human capital in host countries and lowering distance constraints can promote the location choice behaviour of Chinese OFDI (Mingzhe Zhang , 2022[6]; Guanhong Jiang, 2012[7]; Ruizhen Shi, 2022[8]) Weihang Liu (2022)[9] shows that high green development, low human cost and low technology in host countries drive the increase of OFDI in China. Jingjing Wang(2021)[10] tested the heterogeneity in two periods from 2003 to 2014 and 2014 to 2019. The results of the empirical analysis show that the impact of cultural distance on China's OFDI along the "Belt and Road" initiative is more significant after the introduction of the "Belt and Road" initiative. Cultural distance significantly affects China's location choice of OFDI in countries along the Belt and Road, and political distance, cultural distance and geographical distance inhibit China's OFDI in countries along the Belt and Road, while economic distance has a significant positive effect (Han Ju, 2019[11]).

In terms of factors affecting countries along the "Belt and Road", studies have shown that market size, country risk, institutional environment, bilateral investment agreements, trade openness and economic freedom all affect China's OFDI. Some scholars have found that the expansion of market size in countries along the "Belt and Road" has a positive attraction effect on China's OFDI inflows, and China's OFDI reflects a certain market orientation (Shan Liu, 2021[12]; Yaqi Huang, 2021[14]). Yuan Liu(2021)[13] analysis at the country risk level shows that, on the whole, country risk along the route significantly inhibits Chinese OFDI, and the higher the country risk, the stronger the inhibiting effect on Chinese OFDI. In contrast, strong legal system, small government size, efficient regulation, openness and economic freedom of the host country can also effectively attract China's OFDI (Yaqi Huang, 2021[14]; Chia-Ting Wu, 2020[15]).

In terms of technology spillover from China's OFDI to countries along the Belt and Road, there are technology spillover and reverse technology spillover based on the home and host countries.[1] In terms of technology spillover, Boyi Zhu(2022)[16] shows that Chinese OFDI has a significant contribution to the technological innovation capability of countries along the Belt and Road, i.e. there is a significant positive technology innovation capability spillover effect of Chinese OFDI. Peisong Hu (2020)[17] found that Chinese OFDI is the main way for countries along the Belt and Road to acquire technology, and the technology spillover effect of Chinese OFDI to countries along the Belt and Road is mainly achieved through the path of technological progress, while the technical efficiency is very insignificant. In terms of reverse technology spillovers, China's technology spillovers to countries along the Belt and Road are mainly achieved through technological progress, while technological efficiency is very low. As far as the reverse technology spillover effect is concerned, the reverse technology spillover of China's OFDI to manufacturing industries in countries along the Belt and Road actively promotes the upgrading of China's manufacturing industries, and under the Belt and Road Initiative, the reverse technology spillover of China's OFDI to countries along the Belt and Road should show an upward trend (the "One Belt, One Road" initiative). effect should show a rising trend (Tao Pan, 2021[18] and Xiaolei Yang , 2022[19]).

In terms of the trade effects of China's OFDI on countries along the "Belt and Road", Yilei Wang (2022)[20] , Minhan Lu (2021)[21] , Bian Jing (2019)[22] and Chongyang Liu(2019)[23] finds that investment has a significant promotion effect on import and export trade, while China's OFDI to

countries along the route is not only significantly improving China's past trade structure with countries along the route, but also indirectly helping domestic high-tech industries gain access to overseas markets and promoting the optimization of China's industrial structure.

This paper complements the research on China's OFDI as the most representative country among developing countries, as there are few studies on the export trade effects of OFDI in developing countries today. This paper focuses on the impact of China's OFDI on carbon emissions in countries along the "Belt and Road", taking 76 countries along the "Belt and Road" as research objects. By introducing the explanatory variables into the base model and then constructing an extended individual time dual fixed-effect model, the empirical analysis is more detailed and comprehensive.

Based on this, this paper uses empirical analysis to investigate the per capita carbon emission effects of China's OFDI to countries along the "Belt and Road".

2. Related Theories

2.1 The "Pollution Sanctuary" Doctrine

The Pollution Haven Hypothesis emphasizes the concept of 'industrial relocation', which suggests that in order to reduce the higher environmental compensation costs in the home country, firms in developed countries transfer the more polluting and energy-intensive parts of the industrial chain to developing countries through FDI, This contributes to environmental pollution in the host country.

The "pollution sanctuary hypothesis" is valid in a more corrupt country, as shown by studies such as Huay Chong Siew (2022)[24]. More corrupt countries attract more polluting FDI than less corrupt countries. Wang Yujing(2022) [25] and others show that FDI puts pressure on environmental quality in the long run, supporting the 'pollution sanctuary' hypothesis. Apergis Nicholas(2022)[26] suggest that FDI flows from Denmark and the UK to the BRICS increase carbon emissions in the BRICS, supporting the "pollution sanctuary" hypothesis. Some scholars have pointed out that FDI causes exports, which in turn leads to imports and further increases carbon emissions in the long run (Ritu Rana, 2019[27];Dagar Vishal, 2022[28]).

2.2 The "Pollution Halo" Hypothesis

The Pollution Halo Hypothesis(PHH) suggests that foreign-invested enterprises are subject to strict environmental regulations in their home countries and have developed a set of mature environmental management concepts. Through technology spillovers and knowledge diffusion, the inflow of FDI can bring advanced production technologies, clean technologies and advanced management experience, which not only improve the domestic production efficiency of the host country, but also The technology spillover effect increases the unit energy production of the host country and reduces energy consumption and carbon emissions per unit of economic output, which in turn reduces its domestic environmental pollution.

The results of some scholars' studies confirm the "pollution halo" hypothesis. Some scholars have found that PHH is not only ineffective for China, but also for most developing countries, while Chinese investment reduces carbon emissions in host countries and contributes to carbon emission reduction and environmental quality improvement in most economies (Ran Wu, 2021[29]; Lili Feng , 2021[1]; Danyu Zhuang, 2021[30]; Haitao Lan, 2020[31]).

Some scholars have also studied the applicability of the "pollution halo" hypothesis in China. Jie Huang(2015)[32] focuses on the inter-provincial level and uses inter-provincial panel data from 1997 to 2012 as a sample to conduct a combination of empirical and normative studies on the impact of FDI on carbon emissions intensity using dynamic panel models, panel joint cubic system models and panel threshold models. Jinkai Li(2017)[33] and others focus on the prefecture-level city level, selecting annual balanced panel data of 285 prefecture-level cities from 2003 to 2013 for empirical analysis, and the results show that foreign investment contributes to the development of China's carbon emissions through the "demonstration effect", "spillover effect" and The results show that foreign investment has promoted China's environmental technology level through the "demonstration

effect", "spillover effect" and "competition effect", supporting the "pollution halo" hypothesis. Rongping Chang(2022)[34] investigated the causal effect of foreign investment liberalization on air pollution intensity using a double difference method based on the relaxation of foreign investment control policies and the "China Environmental Expansion Input-Output" database at the policy level, and the empirical results showed that the "pollution sanctuary hypothesis" hypothesis is not fully valid in China. The empirical results show that the 'pollution refuge hypothesis' is not fully valid in China, that FDI reduces air pollution intensity, and that FDI can help developing countries to achieve green development goals with more liberalised policies. FDI can help developing countries achieve green development goals with more liberal policies. Xietian Ziguang(2019)[35] used a two-way fixed effects model, quantile regression model and panel threshold regression model to conduct an empirical analysis based on the green total factor productivity of 56 countries along the "Belt and Road" route. The results show that Chinese OFDI has a positive contribution to green TFP in host countries along the Belt and Road, while overall investment from other countries inhibits green TFP growth in host countries. The results show that Chinese OFDI has a positive contribution to green TFP in host countries along the route, while overall investment from other countries inhibits green TFP growth in host countries.

In summary, it can be seen that to a certain extent OFDI can effectively curb carbon emissions and improve the environmental quality of host countries.

2.3 Other Relevant Studies

In more detail, some scholars have fused the two hypotheses, arguing that the two opposing hypotheses are not irreconcilable, such as Weidong Huo(2019)[36], who points out that FDI plays a dual role of "devil" and "angel" in the host country, and that in the period of economic development transition, the innovation effect of FDI will gradually be dominated by the ecological innovation spillover effect. During the period of economic development transition, the innovation effect of FDI will gradually be dominated by ecological innovation spillover, and the natural environment of the host country will directly and indirectly reduce industrial environmental pollution through ecological technology innovation spillover, which makes the environmental effect of FDI satisfy the "pollution halo" hypothesis; while in the early stage of economic development, the innovation effect of FDI will be dominated by production-based innovation, and the natural environment of the host country will directly and indirectly reduce industrial environmental pollution through the production-based innovation effect. This is consistent with the "pollution halo" hypothesis. This is consistent with the "pollution paradise" hypothesis. Zhimin Zhou(2018)[37] used panel data indicators of 268 prefecture-level cities in China from 2003 to 2015 to analyse industrial air pollution emissions, and the results showed that at the inter-provincial level, FDI has a positive impact on total SO2 emissions in the short term, which is consistent with the "pollution paradise" hypothesis; at the prefecture-level city level, FDI has a positive impact on total SO2 emissions, which is consistent with the "pollution paradise" hypothesis. At the prefecture-level city level, based on the higher degree of economic and social development and advanced management, the eastern and high industrial output value regions are more conducive to the advanced demonstration effect of FDI and technology spillover, based on which FDI is negatively correlated with the level of industrial air pollution emissions, in line with the "pollution halo" hypothesis; at the micro level of industrial industries, FDI At the micro level of the industrial sector, the inflow of FDI will reduce the level of air pollution in the industrial sector, so the "pollution halo" hypothesis is valid at the micro level of the industrial sector. The "pollution halo" hypothesis is therefore valid at the micro level in the industrial sector.

Along with the "One Belt, One Road" initiative, academics have gradually focused on China's research on OFDI in countries along the "One Belt, One Road". Among them, scholars at home and abroad have studied the relationship between investment and environmental quality from different perspectives and with different factors, mainly coming to three types of conclusions: "pollution refuge", "pollution halo" and the validity of both hypotheses under different conditions. Some scholars have also argued that economic growth, trade openness, cost of capital and institutional

distance have an impact on environmental quality. This shows that research on the environmental effects of international investment is still controversial, with the main research methods being panel cointegration, threshold effects and spatial measures. At this stage, there are still some shortcomings in the research on the relationship between international investment and CO2 emissions, mainly in the following aspects.

1. Some of the literature uses the method of introducing interaction terms to study the indirect effects of FDI, which is prone to multicollinearity and leads to errors in the results of the empirical analysis.

2. The existing literature mainly focuses on the relationship between investment and carbon emissions in host countries and the direct effect of international investment and pollutant emissions, but there is not much research literature on trade and investment cooperation and environmental issues between China and countries along the route, especially the green development and carbon emissions associated with the "One Belt, One Road" initiative. "The impact of China's OFDI on carbon emissions in countries along the Belt and Road is still an issue worth studying.

3. An Empirical Examination of the Impact of China's OFDI on Carbon Emissions in Countries Along the Belt and Road

3.1 Model Construction and Variable Selection

3.1.1 Model Construction

This paper uses CO2 emissions as the explanatory variable and China's OFDI stock as the core explanatory variable, while referring to the research results of domestic and foreign scholars on the influencing factors of OFDI, and finds that industrial structure, trade openness, labour force, population size and geographical distance all have an impact on carbon emissions, based on which a basic econometric model is established.

$$lnCO_{2i,t} = \alpha + \theta lnOFDI_{i,t} + Cont_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (1)$$

$$Cont_{i,t} = \beta_1 lnGDP_{i,t} + \beta_2 open_{i,t} + \beta_3 lnlabo_{i,t} + \beta_4 lnidusi_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (2)$$

where *i* denotes country, *t* denotes year, and $CO_{2i,t}$ denotes the *i* country *t* emissions per capita in a year, and $OFDI_{i,t}$ denotes China's contribution to *i* country *t* denotes the stock of foreign direct investment in country *i* in year *t*, *Cont* denotes the control variable, and$GDP_{i,t}$ denotes the per capita GNP in country *i* in year *t*, and $open_{i,t}$denotes the degree of trade openness in country *i* in year *t,* and $labo_{i,t}$ denotes the number of labour force in country *i* in year *t*, and $idusi_{i,t}$ denotes the level of industry (value added as a percentage of GDP). ε_i denotes individual effects, and τ_i denotes time effects, and $\varphi_{i,t}$ denotes the random error term. To reduce the impact of the heteroscedasticity problem, the variables are logarithmicised, while the control variables are not logarithmicised because the values of trade openness are small.

3.1.2 Selection of Variables

Explanatory variable ($\ln Co_2$): In this paper, carbon dioxide emissions per capita are used to reflect the carbon emissions of countries along the Belt and Road, because on the one hand, most of the countries along the Belt and Road are developing countries and have abundant mineral and oil resources, and carbon dioxide pollution is the main cause of environmental pollution, and on the other hand, the data on carbon dioxide emissions in various databases are more comprehensive, and the per capita indicator is more representative than the total indicator. emissions in each database is more comprehensive, and the per capita indicator is more representative than the total indicator.

Core explanatory variables (lnOFDI): This paper selects the stock of China's outward foreign direct investment in "One Belt, One Road" countries as the core explanatory variable. Based on the fact that the stock data can represent the status of China's OFDI to "One Belt, One Road" countries in a stable and systematic manner, and considering that the flow data has negative values and there

are many missing data, which are not easy to measure, this paper selects the stock data of China's OFDI to "One Belt, One Road" countries as the core explanatory variable. In this paper, the stock of Chinese OFDI in Belt and Road countries is used to measure the level of Chinese OFDI in Belt and Road countries.

Control variables:

Economic level (lnGDP): In this paper, the GDP of the host country is chosen to reflect the level of the economy. Usually, all other things being equal, GDP growth will on the one hand lead to an increase in the income of the population, which in turn will contribute to stimulating consumption and an increase in the consumption of cars, high-end household appliances, etc., thus prompting enterprises to intensify their use of resources and leading to an increase in carbon emissions.

Trade openness (Open): In this paper, the share of the host country's import and export volume in GDP is used to measure the degree of trade openness. Zhixin Zhang(2020)[38] and others selected data from 61 countries along the Belt and Road as their research samples. The results show that the EKC curves of trade opening and carbon emissions of the countries along the Belt and Road have an inverted U-shape, trade opening will eventually reduce carbon emissions, and environmental pollution problems will eventually be improved with the deepening of trade opening. The EKC curve for trade opening and carbon emissions along the Belt and Road shows an inverted U shape.

Labour force level (lnLabo): The labour force participation rate of the host country is chosen to represent the labour force level in this paper. Wenyan Li (2021) [39] selected data from six provinces from 2008 to 2018 as the study sample, and the findings indicate a high correlation between the size of the labour force and carbon emissions. At the same time, the increase in the number of labour force raises the level of labour force, which further increases productivity and leads to the release of environmental protection policies, which in turn reduces carbon emissions .

Industrial structure (lnIdusi): This paper selects the value added of the secondary sector in the host country as a proportion of GDP to reflect the industrial structure. Along with the industrial revolution, the global industrialization level has increased rapidly, which has led to a great increase in energy demand and resource consumption, followed by an increase in carbon emissions and carbon pollution, making environmental pollution problems increasingly serious, such as rising sea levels, melting mountain glaciers, drastic climate changes and the spread of tropical diseases on a wider scale. The countries along the "Belt and Road" are rich in oil and mineral resources, and industrial development has intensified resource consumption, which is the main cause of environmental pollution, while industrial transformation and upgrading, reducing GDP energy consumption and pollutant emissions, will help reduce damage to the ecological environment and solve environmental problems. Therefore, this paper selects the proportion of the value added of the secondary industry to GDP to reflect the industrial structure, and the higher the value of the proportion indicates that the secondary industry consumes more resources and emits more carbon.

Table 1. Descriptive statistics of variables

Variable name	Meaning of variables	Average value	Standard deviation	Minimum value	Maximum value	Number of samples
$\ln Co_2$	CO2 emissions per capita	9.930	1.777	5.438	14.35	836
lnOFDI	Chinese outward foreign direct investment	9.655	2.469	0	14.29	836
lnGDP	GDP per capita	24.67	1.611	20.54	28.46	836
Open	Trade openness	84.96	45.91	1.219	380.1	836
lnLabo	Labour force level	4.117	0.163	3.619	4.464	836
lnIndusi	Industrial output/GDP	3.210	0.361	1.516	4.222	836

Data sources: World Bank database, China Outward Foreign Direct Investment Statistical Bulletin 2009-2019, CEPII database

3.2 Sample Selection and Data Sources

In order to investigate the effect of China's OFDI on the per capita carbon emissions of OFDI in countries along the "Belt and Road", China's OFDI stock, GNP, trade openness, labour force level and industrial structure were selected as explanatory variables through a large amount of literature, and some countries were excluded because of serious data deficiencies. Some countries were excluded because of serious data deficiencies in some countries. Finally, this paper uses panel data of 76 countries along the route from 2009 to 2019 for the study, which cover both developed and developing countries.

Data sources for the variables: CO2 emissions per capita, gross national product (GDP), openness to trade (open), labour force level (Labo), industrial structure (Indusi) from the World Bank's Development Indicators Database (WDI), and OFDI from China's Outward Foreign Direct Investment (OFDI) from the 2009 to 2019 China Outward Foreign Direct Investment Statistical Bulletin.

3.3 Empirical Results and Analysis

3.3.1 Regression Results and Analysis

(1) Multicollinearity test

Multicollinearity refers to the existence of precise or highly correlated relationships between explanatory variables in a model, which distorts the model estimates. In order to make the data analysis results more scientific and reasonable, this paper uses STATA17.0 software and selects the Variance Inflation Factor (VIF) to test the multicollinearity problem among the explanatory variables. By testing the multicollinearity problem, the value of VIF is used to determine whether there is correlation among the explanatory variables, and if$0 < \mathrm{VIF} < 10$ If there is no multicollinearity, it means that there is no multicollinearity, and if there is multicollinearity, it will lead to incorrect measurement results. The results of the multicollinearity test are shown in Table 2.

Table 2. Multicollinearity test results

Variables	VIF	1/VIF
lnOFDI	1.46	0.685785
lnGDP	1.78	0.562312
Open	1.03	0.972156
lnLabo	1.25	0.797035
lnIdusi	1.27	0.787137
Mean VIF	1.36	

Data source: Compiled from STATA 17.0 calculations.

As can be seen from the table above, the variance inflation factors for each explanatory variable in the model are in the$0 < \mathrm{VIF} < 10$ interval, indicating that there is no multicollinearity problem in the model.

(2) Analysis of regression results

Based on the existence of three panel models in econometrics, in order to make the model selection more credible, this paper makes STATA 17.0 to conduct empirical analysis and select the final model to be used based on the test results. Firstly, the individual effects are tested and the results show that the fixed effects are better than the mixed Ols model. Secondly, the time effect is tested and the test results show that the random effect also outperforms the mixed Ols model. The results of the Hausman test are shown in Table 3

.

Table 3. Hausman test results

Test of H0: Difference in coefficients not systematic
chi2(5) = 264.52
Prob > chi2 = 0.0000

Data source: Compiled from STATA 17.0 calculations.

The model used to conduct the baseline regression analysis in this paper is equation (1). Firstly, the base model is regressed on a double fixed-effects model with the stock of Chinese OFDI and GDP per capita as explanatory variables, while controlling for individuals and time. Finally, based on the regression results, the impact of each factor on carbon emissions in each country along the Belt and Road is explored separately. The extended carbon emission model was constructed as follows.

$$lnCO_{2i,t} = \alpha + \beta_1 lnOFDI_{i,t} + \beta_2 lnGDP_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (3)$$

$$lnCO_{2i,t} = \beta_1 lnOFDI_{i,t} + \beta_2 lnGDP_{i,t} + \beta_3 open_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (4)$$

$$lnCO_{2i,t} = \beta_1 lnOFDI_{i,t} + \beta_2 lnGDP_{i,t} + \beta_3 open_{i,t} + \beta_4 lnlabo_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (5)$$

$$lnCO_{2i,t} = \beta_1 lnOFDI_{i,t} + \beta_2 lnGDP_{i,t} + \beta_3 open_{i,t} + \beta_4 lnlabo_{i,t} + \beta_5 lnidusi_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (6)$$

Table 4. Extended double fixed effects model

Variable name	Model I	Model 2	Model 3	Model 4
lnOFDI	-0.030**	-0.031**	-0.029**	-0.028**
	(-2.34)	(-2.41)	(-2.39)	(-2.36)
lnGDP	0.328***	0.338***	0.330***	0.304***
	(3.93)	(3.71)	(3.77)	(3.74)
Open		0.000	0.000	0.000
		(0.37)	(0.37)	(0.04)
lnLabo			-0.973***	-0.944***
			(-2.77)	(-2.72)
lnIdusi				0.186*
				(1.77)
2009b.year	0.000	0.000	0.000	0.000
	(...)	(...)	(...)	(...)
2010.year	0.019	0.016	0.014	0.017
	(1.52)	(1.09)	(0.99)	(1.26)
2011.year	0.032	0.026	0.026	0.031
	(1.37)	(0.87)	(0.92)	(1.17)
2012.year	0.050*	0.044	0.044	0.050
	(1.77)	(1.32)	(1.37)	(1.58)
2013.year	0.049	0.044	0.043	0.051
	(1.35)	(1.08)	(1.10)	(1.32)
2014.year	0.071*	0.066	0.068	0.077*
	(1.72)	(1.50)	(1.59)	(1.81)
2015.year	0.134***	0.132***	0.134***	0.147***
	(3.47)	(3.31)	(3.47)	(3.63)
2016.year	0.173***	0.171***	0.174***	0.187***
	(4.28)	(4.19)	(4.41)	(4.49)
2017.year	0.178***	0.174***	0.179***	0.193***
	(4.01)	(3.89)	(4.16)	(4.28)
2018.year	0.180***	0.174***	0.178***	0.191***
	(3.45)	(3.23)	(3.43)	(3.68)
2019.year	0.195***	0.190***	0.197***	0.209***
	(3.64)	(3.47)	(3.73)	(3.98)
R-squared	0.381	0.382	0.401	0.414
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
F test	0	0	0	0
r2_a	0.372	0.372	0.391	0.404
F	10.27	10.28	9.958	8.856

Note: ***, **, * denote passing significance tests at 1%, 5% and 10% significance levels respectively, with p-values in brackets.

From the analysis of the regression results in the above table, it can be seen that in the double fixed-effect model, every 1% increase in China's OFDI effectively suppresses the reduction of carbon dioxide emissions in the countries along the route by 0.03%, indicating that China's OFDI has a carbon emission reduction effect on the countries along the route. It shows that after considering the economic level, trade openness, labour force level and industrial structure of each country along the Belt and Road, China's OFDI not only does not aggravate the carbon emissions of the countries along the Belt and Road, but also has a suppressive effect on the growth of carbon emissions of the countries along the Belt and Road, which has a beneficial effect on improving the ecological environment. The empirical results also show that the "pollution sanctuary" hypothesis is not valid for Chinese investments along the Belt and Road.

As far as the control variables are concerned, the coefficient of economic level (lnGDP) is positive at the 1% significance level, indicating that every 1% increase in the level of economic development of the countries along the route leads to a 0.328% increase in the country's CO2 emissions, thus showing that an increase in economic level on the one hand expands the size of enterprises, and on the other hand increases per capita income to stimulate consumption, thus contributing to an increase in the use of energy resources and leading to an increase in carbon emissions. The effect of trade openness (Open) on CO2 emissions is not significant. The negative relationship between labour force level (lnLabo) and carbon emissions is tested at the 1% significance level, implying that the labour force level in the coastal countries suppresses carbon emissions per capita, with each 1% increase in labour force participation rate decreasing carbon emissions per capita by 0.937%, which shows that by increasing the labour force level in the coastal regions, it can effectively improve the productivity of enterprises, and at the same time promote the issuance of environmental protection policies, thus reducing carbon emissions. Industrial structure is an important factor affecting a country's carbon emissions, and industry is one of the main causes of carbon emissions. Overall, the coefficient of industrialization level of the countries along the route is positive at the 10% significance level, and every 1% increase in the industrialization level of the countries along the route as a percentage of GDP increases carbon emissions per capita by 0.186%. However, in the empirical results of Model 4, the coefficient of China's OFDI is still highly significant and negative, reinforcing the effective suppressive effect of China's OFDI on the carbon emissions of the countries along the route. The Blue Book on Outward Investment and Risks points out that, in terms of the countries along the Belt and Road, energy, transportation and information technology are the most important industrial sectors for Chinese OFDI direct investment, and most of the investment projects are environment-friendly projects, and the investment agents have more advanced technology and relatively perfect environmental management standards. Most of the investment projects are environmentally friendly, and the main investors have more advanced technology and relatively sound environmental management standards, which can significantly promote the technological level and management level of local enterprises in the host country through technology spillover effects, thus improving the environmental quality of the host country.

3.4 Robustness Tests

3.4.1 Robustness Testing of the Underlying Regression Results

To further test the robustness of the results of the empirical analysis, this paper draws on Lan, H. (2020) [31] , the relationship between OFDI andCo_2 The endogeneity of the two-way causality problem will lead to errors in the estimation of the model, as it is impossible to distinguish whether Chinese OFDI suppresses the carbon emissions of the countries along the route or the reduction of carbon emissions contributes to the increase of Chinese OFDI, i.e. there will be errors in the determination of the relationship between Chinese OFDI and carbon emissions of the countries along the route. To solve the endogeneity problem, this paper replaces the initial Chinese OFDI stock data with a one-period lag of the core explanatory variable OFDI, so as to eliminate the endogeneity and reduce the estimation bias caused by the endogeneity problem. The specific steps are as follows.

First, a panel regression was conducted with the lagged term of China's OFDI as the core explanatory variable, and the model was constructed as follows.

$$lnCO_{2i,t} = \beta_1 lnL.OFDI_{i,t} + \beta_2 lnGDP_{i,t} + \beta_3 open_{i,t} + \beta_4 lnlabo_{i,t} + \beta_5 lnidusi_{i,t} + \varepsilon_i + \tau_i + \varphi_{i,t} \quad (7)$$

Second, the current period explanatory variables were introduced into the model for a two-effects fixed model regression, the results of which are shown in Tables 5.

Finally, the results of both regressions show that the coefficients of OFDI are significantly negative, as shown in Table x-x. In addition, the effects of economic level, trade openness, labour force level and industrial structure on carbon emissions are consistent with the previous paper and pass the robustness test, thus the results of this paper are robust.

In summary, Chinese OFDI has a significant dampening effect on per capita carbon emissions in countries along the Belt and Road.

Table 5. Results of the robustness test

Explanatory variables	Model I Explanation of substitution Variables	Model 2 Fixed effects Models
L.lnOFDI	-0.021*	
	(-1.85)	
lnOFDI		-0.028**
		(-2.36)
lnGDP	0.248***	0.304***
	(3.18)	(3.74)
Open	0.000	0.000
	(0.06)	(0.04)
lnLabo	-0.974***	-0.944***
	(-3.02)	(-2.72)
lnIdusi	0.194*	0.186*
	(1.95)	(1.77)
Constant	7.299***	5.886**
	(3.22)	(2.47)
Observations	760	836
Number of COUN	76	76

Note: ***, **, * denote passing significance tests at 1%, 5% and 10% significance levels respectively, with p-values in brackets.

4. Conclusion and Policy Recommendations

This paper empirically examines the impact of China's OFDI on the per capita carbon emissions of the countries along the Belt and Road by constructing an extended individual time double fixed effects regression model using panel data of 76 countries along the Belt and Road between 2009 and 2019. The empirical results are as follows:

(1) The carbon emission effect of China's OFDI to countries along the Belt and Road is significantly negative, which supports the "pollution halo" hypothesis. With the addition of other control variables to the model, the carbon emission effect of China's OFDI remains significantly negative, suggesting that the production behaviour of Chinese multinational enterprises is clean and has a beneficial effect on the ecological environment.

(2) Increasing levels of economic development will lead to an increase in CO_2 emissions.

(3) In terms of the industrial structure as a whole, the increase in the level of industrialization, while leading to CO_2 emissions, the increase is smaller, probably because of the clean technologies that Chinese multinational companies bring to countries along the route.

(4) The significant reduction in per capita carbon emissions by the labour force indicates that China brings abundant labour resources to the countries along the Belt and Road, and by increasing the labour force, it can effectively improve the productivity of enterprises, thus reducing carbon emissions and improving the ecological environment.

Based on the results of this paper's empirical analysis, the following recommendations are made to achieve green, healthy and sustainable development between China and countries along the "Belt and Road".

(1) Encourage enterprises to actively "go global" and increase direct investment in countries along the route.

The international environment in which China's OFDI is taking place is undergoing profound changes. The government should assess the situation, strengthen top-level design, take the "One Belt, One Road" as the lead, find the right focus for outbound investment, strengthen multi-level international cooperation, and actively encourage enterprises to "go global". For China, encouraging enterprises to actively "go global" and increase direct investment in countries along the route can raise the level of China's openness to the outside world, nurture large multinational companies with international competitiveness, open up international market space and optimise China's industrial structure.

(2) Both China and the host country should optimise the structure of their investment industries and strengthen multilateral cooperation.

For China, when making OFDI to countries along the Belt and Road, it should mainly focus on low-pollution and high-tech industries, while developing a reasonable classification system based on local resources, environment and socio-economic conditions, paying attention to the quality of China's OFDI, contributing to the economic growth of the countries along the Belt and Road while reducing environmental pollution, and promoting the construction of local sustainable development systems to improve environmental quality. For host countries, countries along the "Belt and Road" should join hands with China to take the low-carbon development path, pay attention to and effectively use the regional cooperation platform of the "Belt and Road", integrate the green development strategy with the innovation-driven strategy in depth, and promote the development of China's green industry. For the host countries, the countries along the Belt and Road should join hands with China to pursue a low-carbon development path, pay attention to and effectively use the regional cooperation platform of the Belt and Road, integrate the green development strategy with the innovation-driven strategy, so that both sides can jointly achieve a green and low-carbon economic transformation and sustainable development.

(3) Countries along the route should pay attention to labour levels and improve production efficiency.

The empirical analysis found that the level of labour force significantly inhibits carbon emissions, indicating that along the economic development of the countries along the route, there is a need to focus on improving the level of labour force development, taking into full consideration the relationship between the level and scale of labour force and production efficiency and carbon emissions, while prompting the release of environmental protection policies to reduce carbon emissions.

(4) Countries along the route should continue to introduce Chinese outward FDI.

Based on the results of the empirical analysis, it can be seen that China's OFDI to countries along the Belt and Road can effectively curb carbon emissions and does not cause environmental pollution, so countries along the route should continue to introduce Chinese OFDI and make full use of the Belt and Road initiative platform to promote The countries along the Belt and Road should continue to import Chinese OFDI and make full use of the Belt and Road Initiative platform to promote their economic development.

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