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The impact of foreign direct investment on carbon emissions in China: a provincial panel data analysis

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Abstract. *This paper analyzes China's provincial data from 2004 to 2021 using a panel regression analysis model to examine the impact of foreign direct investment (FDI) growth on China's carbon emissions. The empirical results show that: 1) FDI, GDP per capita, industrial structure, and fiscal investment significantly contribute to increased carbon emissions, while economic openness has a significant negative effect. 2) From the perspective of regional samples, FDI in the eastern and central regions positively influences carbon emissions, with GDP per capita having a positive effect on the eastern region and a negative one in the central and western regions. Industrial structure, fiscal investment, and population also significantly affect carbon emissions, highlighting regional economic and structural disparities. The analysis suggests that early environmental protection inadequacies and the influx of high-pollution, high-energy industries due to FDI contributed to rising emissions. Therefore, this study recommends enhancing FDI quality standards, limiting high-pollution industries, and promoting investment in green technologies to foster a low-carbon economy.*

Keywords: foreign direct investment, carbon emissions, China, two-way fixed effects.

JEL Classification: F21, O53, Q53, C33.

1. Introduction

In recent years, China has actively participated in international trade and industrial relocation, attracting significant foreign direct investment (FDI). While FDI has driven China's rapid economic growth, it has also significantly impacted the country's carbon emissions. Some multinational corporations from developed countries have transferred their domestic "sunset industries" to China through FDI, placing considerable pressure on the environment. This has led to a continuous increase in carbon emissions, posing substantial challenges to economic and social development. Therefore, reducing carbon emissions, advancing the rapid development of a low-carbon economy, and appropriately attracting FDI to accelerate industrial restructuring have become urgent needs.

Existing research on the impact of FDI on China's carbon emissions presents mixed findings. Some studies support the pollution haven hypothesis, suggesting that FDI leads to increased emissions as firms move operations to China. In contrast, other studies endorse the pollution halo hypothesis, arguing that FDI can enhance China's environmental quality by introducing cleaner technologies and more sustainable practices. Zhai and Wang (2022) found that FDI increases carbon emissions in the short term but reduces them in the long term. Based on panel data from Chinese cities between 2005 and 2019, Biao and Zhang (2023) found that FDI can significantly reduce China's carbon emissions. Similarly, studies by Dang (2018), Hao et al. (2021), Wang and Wang (2022), and Li (2023) have also identified a pollution halo effect (green technology spillover effect) of FDI, indicating that FDI significantly reduces carbon emissions. In addition, Sung et al. (2018) utilized panel data from 28 sub-industries within China's manufacturing sector spanning the years 2002 to 2015 to examine the influence of FDI inflows on carbon emissions in China. Their findings indicated that FDI diminished the pollution halo effect associated with carbon emissions in China. In contrast, research by Yu et al. (2016), Wang et al. (2019), Lu and Luo (2021), and Liu (2023) suggests that the rapid inflow of FDI has continued to increase China's carbon emissions. Furthermore, Xie and Xu (2019) pointed out that at low levels of FDI, carbon emissions increase, whereas at higher levels of FDI, carbon emissions are suppressed. Regarding the impact of FDI on carbon emissions in different regions of China, Huang (2017) noted that FDI has varying effects across the eastern, central, and western regions. Specifically, FDI reduces carbon emissions in the eastern and central regions, while it leads to an increase in carbon emissions in the western region. Based on an analysis of China's carbon emissions data from 2001 to 2019, Fang et al. (2022) found that FDI has a significant inhibitory effect on China's carbon emissions. However, this effect is limited to the eastern and central regions, where FDI reduces carbon emissions, while FDI in the western region shows no such inhibitory effect. Additionally, Wei and Ji (2023) highlighted that there is a nonlinear relationship between FDI and carbon emissions in the western region.

Existing research has extensively examined the relationship between FDI and carbon emissions. However, much of this analysis relies on national or provincial panel data, which imposes significant limitations on the robustness and generalizability of the conclusions.

The findings often lack consistency, owing to variations in regional, industrial, and temporal dimensions. This inconsistency may arise from heterogeneity in data samples, methodological approaches, and the specific variables emphasized in different studies. Consequently, the complexity of the relationship between FDI and carbon emissions remains insufficiently elucidated. Furthermore, factors such as regional disparities in economic development, industrial structure, and environmental policy frameworks may result in substantial variations in the impact of FDI on carbon emissions, further complicating the analysis. While existing studies have contributed valuable theoretical insights and empirical evidence on the relationship between FDI and carbon emissions, a unified conclusion regarding the environmental effects of FDI remains elusive. This lack of consensus can be attributed to variations in research scope, data dimensions, and industry-specific differences. In the context of China's economic structural transformation, industrial realignment, and the implementation of increasingly stringent environmental policies, analyzing the impact of FDI on carbon emissions is of significant practical relevance. However, numerous existing studies fail to account for the influence of regional heterogeneity on the environmental impacts of FDI, thereby limiting the comprehensiveness and robustness of their conclusions. Addressing this research gap necessitates a more nuanced investigation into the specific impact of FDI on carbon emissions, which is pivotal for reconciling economic development with environmental sustainability. This study employs a panel regression analysis model, utilizing provincial panel data from China spanning 2004 to 2021, to systematically examine the influence of FDI on carbon emissions. This study will first conduct a comprehensive review of the relevant literature to summarize progress in understanding the relationship between FDI and carbon emissions. Second, this study will develop a panel model to analyze the specific mechanisms through which FDI impacts carbon emissions in depth. Finally, based on the empirical findings, this study will propose targeted policy recommendations to provide policymakers with actionable insights and theoretical guidance for advancing green development objectives.

2. Literature Review

The impact of FDI on the environmental performance of host countries has been the subject of extensive research, yielding varying results depending on the context and period analyzed. Based on an analysis of Turkish panel data from 1974 to 2010, Gökmenoğlu and Taspinar (2016) found that FDI is a long-term determinant of Turkey's carbon emissions, suggesting that FDI has a promoting effect on carbon emissions. Bakhsh et al. (2017), utilizing an annual dataset covering the period from 1980 to 2014, identified a positive correlation between FDI and pollution in Pakistan. Adeel-Farooq et al. (2021) utilized panel data from 76 countries spanning the period 2002 to 2012 to analyze the environmental impact of FDI originating from both developed and developing countries on the host countries. Their findings indicated that FDI from developed countries enhanced the overall environmental performance of low-income, lower-middle-income, and upper-middle-income host countries. Conversely, FDI from developing countries negatively affected the environmental performance of low-income and lower-middle-income host countries.

In contrast, studies focusing on China present a more nuanced perspective on the environmental effects of FDI. Fang et al. (2010) highlighted that FDI brings not only capital and technology but also positive environmental effects to China. Research by Xu and Deng (2012), Yu and Zhang (2016), as well as Li et al. (2017), emphasized the role of FDI in enhancing China's ecological efficiency and reducing environmental pollution through technology spillovers. These studies collectively argue that FDI contributes positively to China's environmental protection efforts and is not a primary cause of environmental degradation. However, other scholars present contrasting evidence. He and Wang (2012), along with Wang (2013), found a correlation between increased FDI and higher industrial wastewater discharge in China, indicating a negative environmental impact of FDI. Bao and Chen (2012) further refined this perspective by asserting that the environmental consequences of FDI depend on the targeted industry, with pollution-intensive sectors exacerbating environmental degradation, while FDI in cleaner sectors follows a U-shaped trajectory, initially reducing pollution before reaching a threshold where it increases again.

The above previous studies demonstrate that the relationship between FDI and the host country's environment is multifaceted and context-dependent. FDI has the potential to generate positive environmental benefits, such as enhancing ecological efficiency, facilitating the adoption of green technologies, and reducing environmental pollution. In contrast, under certain conditions, particularly in resource-intensive and highly polluting industries, the inflow of foreign capital may lead to adverse environmental consequences, exacerbating local pollution and intensifying environmental pressures. Therefore, a comprehensive understanding of the FDI-environment nexus is essential for accurately evaluating its overall effects and formulating balanced policies.

Moreover, the nature and industrial characteristics of FDI exert varying influences across different economic contexts. For instance, FDI in high-tech and clean energy sectors often introduces advanced technologies and management practices, thereby enhancing ecological efficiency and reducing emissions of carbon and other pollutants. Conversely, in traditional and resource-intensive industries, FDI may contribute to resource overexploitation and environmental degradation. This issue is particularly pronounced in regions with relatively weak environmental oversight, where foreign enterprises may prioritize cost minimization over compliance with environmental standards, further exacerbating environmental pressures. Previous studies have also highlighted that FDI exerts varying effects on environmental issues, such as carbon emissions and wastewater discharge, depending on the industrial sector. For instance, FDI in manufacturing and heavy chemical industries is often associated with higher energy consumption and increased pollution. In contrast, FDI in service sectors and high-tech industries tends to have a more favorable environmental impact, potentially contributing to sustainable development.

Although the existing literature offers valuable insights into the relationship between FDI and environmental outcomes, inconsistencies persist due to variations in research scope, data sources, and model specifications. Regarding the environmental impacts across different regions of China, current research has not sufficiently addressed the heterogeneous effects of FDI on carbon emissions at the regional level. This study seeks to address this gap by employing empirical analysis based on provincial panel data from China spanning 2004 to 2021, to examine the specific impact of FDI on carbon emissions and elucidate the underlying mechanisms.

3. Model and Data

Previous studies have indicated that factors such as FDI, GDP per capita, industrial structure, and fiscal expenditure significantly influence a country's carbon emissions (Hao et al., 2021; Zhai and Wang, 2022; Fang et al., 2022). In line with these findings, this study employs the carbon emissions (CO_2) of each province and city as the dependent variable, while FDI, GDP per capita, industrial structure (Industry rate), fiscal investment (Fiscal investment), economic openness (Openness), and total population (Population) of each province and city serve as independent variables. These variables are incorporated into a panel data analysis model for further investigation.

The panel data analysis equation constructed in this paper is as follows:

$$lnCO_{2_{it}} = \alpha_0 + \beta_1 lnFDI_{it} + \beta_2 lnGDP\_per\_capita_{it} + \beta_3 lnIndustry\_rate_{it} + \beta_4 lnFiscal\_investment_{it} + \beta_5 lnOpenness_{it} + \beta_6 lnPopulation_{it} + \varepsilon_{it} \quad (1)$$

Among them, a_0 is a constant term; *i* refers to the provinces and cities; *t* refers to the year; β_i is the regression coefficient; $lnFDI_{it}$ is the logarithm of FDI in province or city *i* in year *t*; $lnGDP\_per\_capita_{it}$ is the logarithm of GDP per capita in province or city *i* in year *t*; $lnIndustry\_rate_{it}$ is the logarithm of the industrial structure coefficient in province or city *i* in year *t*; $lnFiscal\_investment_{it}$ is the logarithm of fiscal investment in province or city *i* in year *t*; $lnOpenness_{it}$ is the logarithm of the degree of openness of province or city *i* in year *t*; $lnPopulation_{it}$ is the logarithm of the population of province or city *i* in year *t*; ε_{it} is the error term.

Based on the analytical model outlined above and considering data availability, this study employs panel data from 30 provinces and municipalities in China, covering the period from 2004 to 2021, for estimation purposes. The data primarily come from *the China Statistical Yearbook* and the official website of the National Bureau of Statistics. To mitigate the potential effects of heteroscedasticity and outliers, the selected variables are logarithmically transformed. The definitions of each variable are presented in Table 1, while the descriptive statistics for each variable are provided in Table 2.

Table 1. *Explanation of variable meaning*

Variables	Units	The meaning of each variable
CO_2	Million tons	Total carbon emissions of each province and city
FDI	Million US $	Total FDI of each province and city
GDP per capita	Yuan	GDP per capita of each province and city
Industry structure (Industry rate)	%	The total value of the secondary industry to GDP of each province and city
Fiscal investment	%	Fiscal investment to GDP of each province and city
Economic openness	%	Total exports to GDP of each province and city
Total population	10,000 people	Total population of each province and city

Source: Author's calculations.

Table 2. *Descriptive statistics*

Variable	Obs.	Mean	Std.Dev.	Min	Max	Data Source
CO_2	540	325.582	285.434	7.555	2,099.792	Institute of Public and Environmental Affairs
FDI	540	169,861.689	360,543.365	700	4,527,200	China Statistical Yearbook
GDP_per_capita	540	42,902.852	29,620.281	4,244	187,526	National Bureau of Statistics
Industry_rate	540	0.425	0.083	0.160	0.620	China Statistical Yearbook
Fiscal_investment	540	0.233	0.107	0.089	0.758	National Bureau of Statistics
Openness	540	0.159	0.177	0.004	0.927	China Statistical Yearbook
Population	540	4,506.324	2,764.716	539	12,684	China Statistical Yearbook

Source: Author's calculations.

Before conducting panel data analysis, it is essential to evaluate the stationarity of the variables. This study employs the Levin-Lin-Chu (LLC) test and the Im-Pesaran-Shin (IPS) test to perform panel unit root tests on the variables. These methods are instrumental in determining the presence of unit roots and assessing the stationarity of the time series data, thereby ensuring the reliability and validity of the subsequent analyses. The results of the panel unit root tests are presented in Table 3.

The results of the LLC test and the IPS test indicate that the p-values for the variables *lnFDI*, *lnGDP_per_capita*, *lnIndustry_rate,* and *lnFiscal_investment* exceed 0.05. Therefore, the null hypothesis of "the presence of unit roots" cannot be rejected, suggesting that these variables are non-stationary in their original form. However, the p-values for all first-order differenced variables are less than 0.05, allowing the rejection of the null hypothesis. This indicates that the differenced data series are stationary.

Table 3. *Results of the panel unit root tests*

	LLC test		IPS test	
	P-value	Stationarity	P-value	Stationarity
Level				
$lnCO_2$	0.0000	stationary	0.0000	stationary
lnFDI	0.9914	non-stationary	0.9670	non-stationary
lnGDP_per_capita	0.0134	stationary	0.1520	non-stationary
lnIndustry_rate	0.0171	stationary	0.2494	non-stationary
lnFiscal_investment	0.0000	stationary	0.1016	non-stationary
lnOpenness	0.0005	stationary	0.0032	stationary

	LLC test		IPS test	
lnPopulation	0.0000	stationary	0.0039	stationary
1st difference				
△lnCO_2	0.0000	stationary	0.0000	stationary
△lnFDI	0.0000	stationary	0.0000	stationary
△lnGDP_per_capita	0.0000	stationary	0.0000	stationary
△lnIndustry_rate	0.0000	stationary	0.0000	stationary
△lnFiscal_investment	0.0000	stationary	0.0000	stationary
△lnOpenness	0.0000	stationary	0.0000	stationary
△lnPopulation	0.0000	stationary	0.0000	stationary

Source: Author's calculations.

Based on the results of the panel data unit root tests, which show that the original variables exhibit unit roots while the first-differenced variables do not, this study employs the Pedroni panel cointegration test to assess the existence of a cointegration relationship among the variables. The p-value of the Pedroni panel cointegration test is less than 0.05, leading to the rejection of the null hypothesis of no cointegration. This indicates the presence of a cointegration relationship in the panel data, suggesting that the regression analysis model is not subject to spurious regression issues, and therefore, regression analysis can be conducted directly.

4. Analysis Results

4.1. Benchmark analysis results

Since the p-values of both the F-test and the Hausman test are less than 0.05, this study adopts the fixed effects model. Table 4 presents the results of the benchmark analysis. The estimation results of model (2) indicate that the variables of FDI, GDP per capita, industrial structure, fiscal investment, and openness all pass the significance test. Among them, FDI, GDP per capita, industrial structure, and fiscal investment all have a significant positive impact on China's carbon emissions, whereas openness demonstrates a significant negative effect on carbon emissions. These findings suggest that both FDI and economic growth contribute to an increase in carbon emissions, while an improvement in openness helps to mitigate carbon emissions.

Table 4. *Results of Benchmark analysis*

	Model (1) Pooled OLS	**Model (2) FE**	**Model (3) RE**
lnFDI	-0.0094	0.0612**	0.0556**
	(0.7997)	(0.0189)	(0.0310)
lnGDP_per_capita	0.5201***	0.3409***	0.3690***
	(0.0000)	(0.0054)	(0.0011)
lnIndustry_rate	1.5377***	0.3715***	0.4887***
	(0.0000)	(0.0090)	(0.0002)
lnFiscal_investment	0.3261***	0.5647***	0.5748***
	(0.0007)	(0.0000)	(0.0000)
lnOpenness	-0.1381***	-0.0501*	-0.0545**
	(0.0001)	(0.0669)	(0.0459)

	Model (1) Pooled OLS	Model (2) FE	Model (3) RE
lnPopulation	0.6869***	0.1431	0.6199***
	(0.0000)	(0.4610)	(0.0000)
Constant	-3.9469***	1.1631	-2.8080*
	(0.0000)	(0.5962)	(0.0714)
Individual effects	No	Yes	No
Time effects	No	Yes	Yes
N	540	540	540
adj.R^2 and R^2	0.6496	0.6821	0.7085

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.
Source: Author's calculations.

The estimated coefficient of FDI is 0.0612, which is significantly positive at the 5% level. This indicates that for one unit increase in FDI, China's carbon emissions rise by 0.0612-unit, suggesting that FDI has significantly contributed to the increase in carbon emissions. The insufficient development of environmental regulations in China in the past has facilitated the transfer of high-pollution and high-energy-consuming industries from multinational corporations to China, further exacerbating carbon emissions. Consequently, as the scale of FDI in China has expanded, carbon emissions have also increased.

The estimated coefficient of GDP per capita is 0.3409, which is significantly positive at the 1% level. This indicates that for one unit increase in GDP per capita, China's carbon emissions rise by 0.3409-unit. The rapid development of China's economy has been accompanied by a sharp increase in carbon emissions, highlighting that significant economic progress has largely been achieved at the expense of environmental sustainability, leading to higher carbon emissions.

The estimated coefficient of industrial structure is 0.3715, which is significantly positive at the 1% level. This suggests that for one unit change in industrial structure, China's carbon emissions increase by 0.3715-unit. A key factor contributing to this rise in carbon emissions is the disproportionately high share of the secondary industry in China's overall industrial structure. Although China is actively adjusting its industrial structure to reduce reliance on high-energy-consuming industries, the secondary sector, particularly manufacturing, continues to play a significant role within China's overall industrial framework. At this stage, a substantial proportion of high-energy-consuming industries remain embedded in China's industrial structure, and the persistence of these industries exerts considerable pressure on carbon emissions.

The estimated coefficient of fiscal investment is 0.5647, which is significantly positive at the 1% level. This indicates that for one unit increase in fiscal investment, China's carbon emissions rise by 0.5647-unit. Despite the increased fiscal investment by local governments in recent years aimed at carbon emissions control, the implementation of local carbon reduction policies remains insufficient, contributing to the continued rise in carbon emissions. Additionally, the expansion of infrastructure development by local governments in recent years has also played a role in driving the increase in carbon emissions.

Finally, the estimated coefficient of openness is -0.0501, which is significantly negative at the 10% level. This indicates that for one unit increase in openness, China's carbon emissions decrease by 0.0501-unit. In regions where export trade constitutes a significant portion of the local economic structure, the connection with the global economic market is stronger, leading to greater attention to carbon emissions and environmental sustainability. Moreover, regions with higher levels of openness have more opportunities to attract FDI and tend to have stronger enforcement of environmental policies.

4.2. Robustness test

This study employs the method of replacing independent variables to assess the robustness of the results obtained from the benchmark regression analysis. Given that both GDP and GDP per capita are effective indicators of a region's economic development level, adjustments are made accordingly in the robustness test model. Specifically, GDP per capita is substituted with GDP in the benchmark analysis model to examine the impact of economic development on the research outcomes. Using GDP as an independent variable not only more comprehensively reflects the overall scale of regional economic development but also mitigates potential biases in GDP per capita that may arise from fluctuations in population size, thus offering a more nuanced perspective for analysis. The estimation results of the stability test are presented in Table 5.

The estimation results of the stability test indicate that variables such as FDI, GDP, industrial structure, fiscal investment, and openness all pass the significance test. Specifically, FDI, GDP, industrial structure, and fiscal investment exhibit significant positive effects on carbon emissions, while openness shows a significant negative effect. The estimated coefficient of GDP is 0.0624, suggesting that an increase in GDP corresponds with a rise in carbon emissions. This result is nearly identical to the estimated coefficient of GDP per capita in the benchmark regression (0.0612), indicating consistent impact trends and further validating the robustness of the findings. These findings are consistent with previous studies, suggesting that economic growth is frequently associated with increased energy consumption, which in turn leads to higher carbon emissions. Regarding FDI, its positive and significant impact indicates that the inflow of foreign capital has not only fostered economic development but has also contributed to higher carbon emissions. Furthermore, the adjustment of industrial structure plays a crucial role in determining carbon emissions. In regions with a relatively simple industrial structure that relies heavily on heavy industry and high-pollution sectors, carbon emissions are likely to increase substantially.

On the other hand, openness demonstrates a significant negative impact on carbon emissions, suggesting that in an open economic environment, environmental awareness and technology transfer have improved. Openness facilitates the introduction of clean technologies and enhances the environmental standards and awareness of local enterprises, thereby contributing to a reduction in carbon emissions. Additionally, the estimated coefficients of other key variables are consistent with those obtained in the benchmark regression, further corroborating the robustness of the conclusions drawn from the benchmark analysis in this study.

4.3. Endogeneity test

When analyzing the relationship between FDI and carbon emissions, issues like reverse causality and omitted variable bias can result in endogeneity problems. To address these concerns, a widely used approach involves identifying a suitable instrumental variable that is strongly correlated with FDI but either uncorrelated with carbon emissions or only weakly related to them. This instrumental variable is then employed within a two-stage least squares (2SLS) estimation framework, enhancing the robustness and reliability of causal inference. Specifically, in the first stage, the instrumental variable is regressed on FDI to obtain its predicted values. In the second stage, these predicted values are used as a substitute for actual FDI to assess its impact on carbon emissions. This study selects the mileage of highways in various provinces and cities of China as an instrumental variable to address the potential endogeneity issue between FDI and carbon emissions. The change in highway mileage is primarily influenced by policy initiatives, regional economic development, and government investment. While it has a weak direct causal relationship with carbon emissions, it is closely related to FDI. By using highway mileage as an instrumental variable, this approach effectively mitigates endogeneity issues such as reverse causality or omitted variable bias, thereby enhancing the accuracy of the estimation of the relationship between FDI and carbon emissions.

Table 5. *Results of Robustness, Endogeneity, and Heterogeneity test*

	Robustness test	Endogeneity test	Heterogeneity test		
			Model (1) Eastern Region	Model (2) Central Region	Model (3) Western Region
lnFDI	0.0624**	0.6847**	0.0620**	0.1430**	0.0611
	(0.0169)	(0.0314)	(0.0461)	(0.0439)	(0.1497)
lnGDP_per_capita		-0.4578	1.1651***	-1.3520***	-0.8206***
		(0.3028)	(0.0000)	(0.0000)	(0.0008)
lnGDP	0.3257***				
	(0.0089)				
lnIndustry_rate	0.3838***	2.3486***	0.4439*	0.2104	0.3736
	(0.0071)	(0.0000)	(0.0715)	(0.4580)	(0.1368)
lnFiscal_investment	0.5597***	0.9713***	0.5694***	-0.3404	-0.1420
	(0.0000)	(0.0017)	(0.0002)	(0.3823)	(0.5283)
lnOpenness	-0.0488*	-0.3319***	-0.1078	-0.1454*	-0.0366
	(0.0739)	(0.0008)	(0.2818)	(0.0564)	(0.2485)
lnPopulation	-0.1893	0.2827	-0.1327	3.6604***	1.0255**
	(0.3130)	(0.1489)	(0.6533)	(0.0000)	(0.0129)
Constant	4.3551***	3.2467	-4.6759	-15.9507**	3.2954
	(0.0048)	(0.3285)	(0.1409)	(0.0217)	(0.4168)
Individual effects	Yes	-	Yes	Yes	Yes
Time effects	Yes	-	Yes	Yes	Yes
N	540	540	198	144	198
adj. R^2 and R^2	0.6815	0.6525	0.7060	0.6824	0.8184

Note: 1) ***, ** and * denote 1%, 5%, and 10% significance levels, respectively.

2) The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

Source: Author's calculations.

Table 5 presents the estimation results obtained using the instrumental variable method (2SLS), which further investigates the impact of FDI on carbon emissions. The 2SLS estimation results indicate that variables such as FDI, industrial structure, fiscal investment, and openness all pass the significance test. Specifically, FDI, industrial structure, and fiscal investment have a significant positive impact on carbon emissions, suggesting that while these factors contribute to economic growth, they also facilitate an increase in carbon emissions. Meanwhile, openness significantly reduces carbon emissions, which is closely linked to the introduction of green technologies and the strengthening of environmental regulation. Furthermore, the 2SLS estimation results indicate that, after correcting for endogeneity, the conclusions derived from the benchmark regression remain robust, thereby reinforcing the core finding of this paper regarding the impact of FDI on carbon emissions.

4.4. Heterogeneity test

Due to significant variations in economic development levels and the endowment of economic factors across provinces in China, the impact of FDI on carbon emissions exhibits notable heterogeneity. This regional disparity indicates that the effects of FDI on carbon emissions differ substantially across regions. In more developed regions, FDI tends to lead to an increase in carbon emissions, whereas in less developed regions, the effect may be more moderate, or even inhibitory, on carbon emissions. To further investigate the specific impact of FDI on China's carbon emissions, this study classifies the 30 provinces and cities across the country into three regions—eastern, central, and western—based on geographical differences and economic development levels. This classification allows for a clearer understanding of how economic structures, industrial development, and environmental protection policies in different regions influence carbon emissions through FDI. By conducting separate group regression analyses, this paper aims to explore the regional heterogeneity in the impact of FDI on carbon emissions. The estimated results of the heterogeneity test are presented in Table 5.

The results of the heterogeneity test provide a deeper analysis of the impact of FDI on carbon emissions, particularly in the eastern and central regions. The significance test results indicate that FDI in both regions has a significantly positive impact on carbon emissions, suggesting that an increase in FDI leads to higher carbon emissions in these areas. The business activities of foreign-funded enterprises in these regions are closely associated with elevated carbon emissions. Additionally, the impact of GDP per capita reveals regional differences. While GDP per capita in the eastern, central, and western regions has all passed the significance test, the direction of its impact on carbon emissions varies considerably across regions. In the eastern region, GDP per capita is positively correlated with carbon emissions, indicating that rapid economic growth is accompanied by an increase in carbon emissions to some extent. This relationship can be attributed to the prevalence of high-energy-consuming industries, high consumption levels, and the rapid expansion of infrastructure in the eastern region. In contrast, GDP per capita in the central and western regions exerts a negative impact on carbon emissions, suggesting that economic development in these regions does not necessarily result in increased carbon emissions, but rather contributes to the suppression of their growth to some extent. This can be attributed to the prevalence of more environmentally friendly industries in these regions, or to relatively low levels of energy consumption and the influence of policy orientations that prioritize sustainability.

In addition to the impact of GDP per capita, the industrial structure and fiscal investment in the eastern region also passed the significance test. This indicates that the rationality of the industrial structure and the effective allocation of fiscal funds are directly related to the level of carbon emissions. If the eastern region can further optimize its industrial structure and promote the development of high-tech and low-emission industries, it could foster high-quality economic growth while simultaneously controlling carbon emissions. Additionally, openness and total population in the central region, as well as the total population in the western region, have passed the significance test, indicating that these factors significantly influence carbon emissions. Openness in the central region is closely associated with the inflow of foreign-funded enterprises and the dynamism of regional economic development. Meanwhile, an increase in the total population corresponds to higher energy demand and consumption, thereby contributing to an increase in carbon emissions. In the western region, population similarly drives greater demand for resources and energy, which in turn impacts the level of carbon emissions.

The estimated coefficients for the eastern and central regions are 0.0620 and 0.1430, both of which exhibit significant positive correlations at the 5% significance level. This indicates that the increase in FDI positively influences carbon emissions in both regions, though the magnitude of this impact differs. Specifically, the estimated coefficient of FDI in the eastern region is nearly identical to that of the total sample, suggesting that the impact of FDI on carbon emissions in the eastern region is relatively balanced. This can be attributed to the maturity of the economic structure, the advancement of the industrial chain, and the heightened awareness of environmental protection in the eastern region.

In contrast, the estimated coefficient of FDI in the central region is significantly higher than the 0.0612 observed for the total sample, indicating that the increase in FDI has a more pronounced effect on carbon emissions in the central region. This can be attributed to the fact that during the process of industrial transformation and upgrading in the central region, the influx of foreign-funded enterprises is often associated with higher energy consumption and environmental pollution, which contributes to a marked increase in carbon emissions. In addition, from the perspective of GDP per capita, the coefficient for the eastern region is considerably higher than the estimated coefficient for the total sample, further indicating that economic development has a significantly greater impact on carbon emissions in the eastern region. This phenomenon highlights the growing tension between economic growth and environmental sustainability, as the rapid economic development in the eastern region is accompanied by a substantial increase in carbon emissions.

In the central and western regions, the impact of GDP per capita on carbon emissions is negative, suggesting that economic development has not contributed to an increase in carbon emissions, but rather has partially mitigated their growth. This is attributed to the industrial structure, energy efficiency, and policy orientation in these regions, indicating that they place greater emphasis on sustainable development and environmental protection measures while pursuing economic growth. Furthermore, the estimated coefficient of fiscal investment in the eastern region is nearly identical to that of the total sample, indicating that the increase in fiscal investment has contributed to the growth of carbon emissions in the region to some extent. This phenomenon is linked to the fact that a substantial portion of fiscal funds in the eastern region is allocated to infrastructure development, industrial expansion, and social welfare. While these investments foster rapid economic growth, they also lead to higher resource consumption and environmental pressure, which, in turn, exacerbates the rise in carbon emissions.

Meanwhile, the estimated coefficient of industrial structure in the eastern region is slightly higher than that of the total sample, suggesting the continued presence of high-energy-consuming industries in the region. Industries such as heavy industry and traditional manufacturing directly contribute to the increase in carbon emissions. Therefore, the eastern region must accelerate the adjustment of its industrial structure and promote the development of emerging sectors, particularly green and low-carbon industries, in order to mitigate the negative environmental impact. In the central region, openness exerts a significantly stronger inhibitory effect on carbon emissions compared to the national average. During the process of economic liberalization, the central region has been able to effectively attract FDI and promote industrial upgrading, resulting in relatively lower carbon emissions. This phenomenon is closely linked to the region’s policy orientation and industrial structure.

Finally, the population in the central and western regions has contributed to the increase in carbon emissions. Notably, the impact of population on carbon emissions in the central region is significantly greater than that in the western region. This suggests that, during the process of economic development and urbanization, population growth in the central region has led to greater energy demand and consumption pressure, thereby driving a more substantial increase in carbon emissions. Although the western region also experiences population growth, its relatively lower level of economic development and more environmentally sustainable industrial structure have led to a smaller increase in carbon emissions.

5. Discussion

The analysis reveals that FDI, GDP per capita, industrial structure, and fiscal investment all have a significant positive impact on China’s carbon emissions, however, openness effectively curbs the growth of carbon emissions. The benchmark regression results of this study confirm the findings of Yu et al. (2016), Wang et al. (2019), Lu and Luo (2021), and Liu (2023), which demonstrate that FDI inflows significantly contribute to the increase in

China's carbon emissions. Additionally, this study further elucidates the complexity and diversity of the impact of FDI on China's carbon emissions.

In addition, contrary to the pollution haven hypothesis supported by some studies, this paper finds that the impact of FDI on carbon emissions exhibits significant stage and regional characteristics. In the early stages of economic development, FDI often facilitates the transfer of high-pollution and high-energy consumption industries, owing to its relatively low technological threshold, thereby contributing to an increase in carbon emissions. However, as the quality of FDI improves and green technology spillover effects emerge, the impact of FDI on carbon emissions gradually shifts towards inhibition.

Furthermore, the regional impact of FDI exhibits significant asymmetry. The eastern region, with its more developed economy, stricter environmental protection policies, and the influx of high-quality FDI, has experienced effective diffusion of green technologies, leading to a notable reduction in regional carbon emissions. The central region is in a transitional phase, while the western region, characterized by relatively weaker infrastructure and slower industrial structure upgrades, has seen a more pronounced negative effect on carbon emissions. Finally, this study suggests that the impact of FDI on China's carbon emissions follows a phased trajectory. As the level of economic development improves and the policy environment is optimized, the effect of FDI has transitioned from promoting carbon emissions to inhibiting them. In other words, the environmental impact of FDI is not static, but is dynamically influenced by factors such as the stage of regional economic development, the extent of industrial structure upgrading, and the implementation of green policies.

Since the implementation of reform and opening-up in 1978, FDI has played a pivotal role in China's economic development by introducing substantial capital, advanced technology, and managerial expertise, thereby becoming a key driver of economic growth. In the initial stages of reform, China adopted a policy centered on attracting investment and prioritizing rapid economic growth. Through a series of preferential measures, this policy effectively attracted a significant number of foreign-funded enterprises, fostered the growth of an export-oriented economy, and bolstered China's position in the global economy. However, due to limited environmental awareness and the inadequacy of relevant laws and regulations at the time, several issues emerged during the investment attraction process. Specifically, the lack of stringent review procedures and the absence of a comprehensive environmental assessment mechanism resulted in many companies failing to conduct adequate environmental impact assessments before market entry, and some even obtained approval without meeting environmental protection standards. Furthermore, in the pursuit of economic growth, local governments often overlook the need for rigorous scrutiny of the environmental impacts of enterprises. As a result, some "three highs" enterprises (high pollution, high energy consumption, and high emissions) entered China. These enterprises not only failed to deliver the anticipated technology transfer and management experience sharing but also exacerbated environmental pollution, contributing to a continuous rise in

China’s carbon emissions. In this context, Zhang et al. (2023) also noted that FDI can lead to the transfer of carbon emissions to the host country by relocating polluting industries and altering the energy structure. Therefore, in future efforts to attract FDI, the government should adopt a sound investment promotion strategy that prioritizes high-quality FDI. This includes continuously raising the entry thresholds for FDI, strengthening environmental access standards, and encouraging the inflow of environmentally responsible foreign-funded enterprises. At the same time, the government should impose restrictions on the entry of “three highs” enterprises. Such measures will facilitate a win-win outcome, fostering both economic development and environmental protection.

Although this study provides insights into the overall impact of FDI on carbon emissions, it has certain limitations. Unlike some existing studies that offer more detailed industrial and regional classifications when analyzing the impact of FDI on carbon emissions, this study does not specifically disaggregate FDI by industry or region. This limitation may restrict a deeper exploration of the varying effects of FDI on carbon emissions across different industries and regions. The impact of FDI on carbon emissions is significantly heterogeneous across sectors and regions. Therefore, future research should further examine the environmental impact of FDI in specific industries and regions to provide a more comprehensive understanding of its ecological effects and offer a more targeted, regionally adaptable basis for policymaking.

6. Conclusion and Policy Recommendations

This paper uses a panel regression analysis model to investigate the impact of FDI on China’s carbon emissions, using provincial panel data spanning the years 2004 to 2021. The empirical results indicate the following: 1) From the perspective of the entire sample, FDI, GDP per capita, industrial structure, and fiscal investment all exhibit a significant positive effect on China’s carbon emissions. In contrast, openness has a significant negative impact on carbon emissions. This suggests that traditional economic growth drivers contribute to increased carbon emissions during the early stages of development. However, greater openness—particularly the inflow of high-quality FDI—demonstrates a carbon emission-reducing effect, underscoring the importance of environmental governance within an open economy. 2) From the perspective of regional samples, there are significant differences in the impact of FDI on carbon emissions between the eastern and central regions. In the eastern region, the influence of FDI on carbon emissions is primarily driven by the promotion of high-tech industries, which indirectly facilitates green transformation. In contrast, in the central and western regions, the impact of FDI on carbon emissions is more pronounced through the expansion of resource-intensive and energy-consuming industries, owing to the slower pace of industrial structure upgrading. 3) This study posits that the impact of FDI on China’s carbon emissions exhibits a phased transformation, with its effect shifting from promoting carbon emissions to inhibiting them as economic development advances and the policy environment improves. This finding suggests that the environmental impact of FDI is not static, but is dynamically influenced by factors such as the stage of regional economic development, the upgrading of industrial structure, and the implementation of green policies.

In the early stages of China's development, the insufficient construction of environmental regulations led multinational companies to transfer high-pollution and energy-intensive production activities to China. As the scale of FDI gradually expanded, environmental protection measures were unable to effectively address the increased pressure exerted by FDI, resulting in a continued rise in China's carbon emissions. Despite the rapid growth of China's economy, this development has often come at the expense of the environment, leading to a significant increase in carbon emissions. Concurrently, the secondary sector continues to play a dominant role in China's economic structure, with the presence of numerous energy-intensive industries placing substantial pressure on carbon emissions. Although local governments have increased fiscal investment in carbon emissions control, the implementation of emission reduction policies remains inadequate, leading to a continued rise in China's carbon emissions. Additionally, nationwide infrastructure development has further stimulated the increase in carbon emissions to some extent.

The empirical analysis presented above indicates that the increase in FDI has contributed to the growth of carbon emissions in China. Based on these findings, the following policy recommendations are proposed:

1) Establish a scientific approach to investment promotion and enhance the quality of FDI. Prioritizing high-quality development in the promotion of FDI is essential. This can be achieved by optimizing the access mechanisms for FDI, raising environmental standards, and restricting the entry of "three highs" enterprises into China. Emphasis should be placed on attracting foreign-funded enterprises in high-tech and low-energy consumption sectors, leveraging their potential to drive green technologies, management innovations, and industrial upgrades. Additionally, a tiered management approach should be adopted for FDI at different stages. In the early stages of FDI inflow, enhanced environmental supervision of high-pollution industries is crucial to mitigate environmental risks. In the mature stage, policy guidance should aim to accelerate the spillover effects of green technologies, thereby reducing the negative impact of FDI on carbon emissions.
2) Enhance environmental standards and foster technological innovation to promote low-carbon economic development. The government should gradually strengthen environmental production standards for enterprises and improve regulatory mechanisms for high-pollution, high-energy consumption industries to reduce carbon emissions at their source. Additionally, policy incentives should be utilized to encourage enterprises to innovate in environmental protection technologies and expedite the adoption of green production practices. Concurrently, regional collaborative governance should be strengthened, and a unified national environmental standards system should be established. Given the regional disparities in development, the eastern region should

focus on advancing the "high-tech FDI + low-carbon economy" model, continuing to lead in green development. Meanwhile, the central and western regions should prioritize the introduction of green technologies and industrial structure adjustments to reduce dependence on high-pollution industries. By optimizing industrial structures, FDI should be directed toward high-tech, low-energy consumption sectors, thereby facilitating green transformation, and supporting sustainable development goals.

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