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The Impact of Green Taxation on Climate Change Mitigation Under Fiscal Decentralization: Evidence from China

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Abstract

Against the backdrop of China's "dual-carbon" goals, the complex interplay between fiscal decentralization and green taxation presents significant challenges for climate governance. This study examines the impact of green taxation on carbon emissions within the context of fiscal decentralization, with a particular focus on spatial spillover effects and multidimensional indicators of fiscal decentralization. Drawing on panel data from 30 Chinese provinces between 2007 and 2022, we apply spatial Durbin and moderating effect models to examine these relationships. Our findings reveal a counterintuitive positive association between green taxation and carbon emissions, indicating the presence of a "green paradox." Furthermore, the three dimensions of fiscal decentralization—revenue decentralization, expenditure decentralization, and fiscal autonomy—demonstrate heterogeneous relationships with carbon emissions, including inverted U-shaped, U-shaped, and linear patterns, respectively. The interaction effects between green taxation and fiscal decentralization also exhibit notable spatial spillover effects and emission reduction potential. The contribution of this study lies in its integrated analysis of multidimensional fiscal decentralization, spatial econometric methods, and underlying mechanisms, thereby addressing underexplored dimensions of China's environmental fiscal policy. These findings not only provide policy insights for China but also offer valuable references for other developing and transitional economies striving to align fiscal and environmental governance.

Keywords: global warming; green taxation; carbon emissions from energy consumption; fiscal decentralization

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1. Introduction

The rapid development of human industrial civilization, while driving significant cultural, economic, and social progress, has also resulted in substantial accumulations of carbon dioxide emissions. This has led to rising atmospheric greenhouse gas concentrations and exacerbated global warming. Against the backdrop of greenhouse gas emissions stemming from traditional production methods and energy structures (G. Chen & Zhang, 2010; Hamit-Haggar, 2012; Ali et al., 2022), countries worldwide have begun exploring green development pathways aimed at reducing greenhouse gas emissions. The core solution to this challenge lies in decreasing carbon dioxide emissions, making carbon reduction a focal point for global governmental exploration. In response to global warming, since 2009, the Chinese government has continuously strengthened its carbon emission governance system by incorporating binding carbon intensity targets into its 12th Five-Year Plan. Although official data indicate a slowing growth rate of carbon emissions, China's total carbon emissions remain among the highest globally (H. Wang et al., 2015; Geng et al., 2011).

In 2020, the Chinese government set forth the goals of "carbon peaking and carbon neutrality" (hereinafter referred to as the "dual-carbon" goals). The Chinese government has progressively raised its carbon reduction targets and actively implemented them, underscoring its role as a key player in addressing global warming. To achieve the "dual-carbon" goals, the Chinese government has highlighted the guiding role of green taxation and initiated a series of greenhouse gas governance measures based on the reform of the green tax system. These efforts have focused on the mechanisms linking green taxes, economic growth, and carbon emissions. In 2018, the Environmental Protection Tax Law of the People's Republic of China was enacted and implemented, marking the establishment of a green tax system with Chinese characteristics that integrates multiple tax categories and policies. Within this context, it is crucial to examine the impact of green taxation on carbon emissions and explore practical strategies for reducing carbon emissions under China's fiscal decentralization framework to promote high-quality economic development.

The paper is structured as follows: Section 2 provides a comprehensive literature review and outlines the theoretical framework. Section 3 details the variable selection and model specification. Sections 4 and 5 present the empirical results and discuss their implications. Section 6 concludes with policy recommendations and identifies the limitations of the study.

2. Literature Review and Theoretical Framework

2.1. The Impact of Green Taxation on Environmental Quality

The study of green taxation and environmental quality originates from Pigou's seminal proposition that taxes can correct negative externalities. Baumol and Oates (1971) further formalized the theoretical foundation, demonstrating that environmental taxes can serve as an effective instrument for mitigating externality-related inefficiencies. Empirical studies such as Hao et al. (2021) and Dogan and Skare (2022) provide robust evidence supporting the efficacy of environmental taxes in reducing carbon emissions, particularly in developed and environmentally proactive countries. However, findings within the Chinese context are more heterogeneous. He et al. (2016) argue that resource taxes exert only indirect effects on carbon emissions, with poorly designed tax increases potentially yielding unintended consequences. In contrast, Xu and Zhang (2018) employ CGE modeling to show that coal resource tax reforms can significantly reduce carbon emissions. Tang (2022) advocates for the establishment of an integrated green tax system to support China's pursuit of its "dual carbon" goals.

Two dominant theoretical perspectives frame this debate: the Pigouvian view, which posits that green taxes reduce emissions by disincentivizing fossil fuel use and promoting clean technology adoption (Liu et al., 2024), and the "green paradox" perspective (van der Ploeg & Withagen, 2012; van der Ploeg, 2013; Sinn, 2008), which cautions that anticipated future tax increases may accelerate current extraction and consumption of carbon-intensive resources. Furthermore, empirical evidence confirms the presence of significant spatial correlations in emissions across regions, reinforcing the likelihood that stringent environmental taxation in one area may displace pollution-intensive activities to adjacent regions—a pollution haven effect (Zhong et al., 2024). This dynamic motivates the formulation of the following competing hypotheses:

H1a: *Green taxation reduces localized carbon emissions.*

H1b: *Green taxation increases localized carbon emissions.*

2.2. Fiscal Decentralization: A Double-Edged Sword for Environmental Governance

The environmental implications of fiscal decentralization remain a subject of debate. Magnani (2000) incorporates fiscal decentralization into the framework of the Environmental Kuznets Curve (EKC), proposing that it may shift the curve leftward, implying earlier environmental improvements. In contrast, Sigman (2007) finds an international association between higher fiscal decentralization and deteriorating water quality. Research conducted in China similarly yields mixed findings: K. Z. Zhang et al. (2011) and Tian and Wang (2018) demonstrate that fiscal decentralization—particularly expenditure decentralization—intensifies carbon emissions and generates positive spatial spillovers. Other studies, such as B. Wang et al. (2019), identify regional heterogeneity, with pronounced emission increases in central and eastern regions, but minimal effects in western provinces. Li (2020) and Gao et al. (2023) further emphasize the nonlinear and spatially heterogeneous impacts of decentralization.

China's fiscal decentralization structure, established through the 1994 tax-sharing reform, fundamentally shapes local government incentives. In the early stages of development, decentralization may prioritize economic growth at the expense of environmental protection. However, beyond a certain economic threshold, rising public demand for environmental quality may alter this trajectory. Moreover, strategic interactions among local officials within the cadre promotion tournament system foster spatial competition and environmental spillovers. Based on these considerations, we propose the following hypotheses:

H2a: *Fiscal expenditure decentralization exhibits an inverted U-shaped relationship with local carbon emissions and a U-shaped relationship with emissions in neighboring provinces.*

H2b: *Fiscal revenue decentralization demonstrates an inverted U-shaped relationship with local carbon emissions and a U-shaped relationship with emissions in neighboring provinces.*

H2c: *Financial autonomy displays an inverted U-shaped relationship with local carbon emissions and a U-shaped relationship with emissions in neighboring provinces.*

2.3. The Spatial Spillover Effects of Environmental Policies

Environmental policies frequently generate spillover effects across jurisdictions. Carbon emissions display significant spatial dependence (Anselin, 2001; L. Wang et al., 2024; Xin et al., 2018), indicating that policy decisions—or the lack thereof—in one region can influence environmental outcomes in neighboring areas. The pollution haven hypothesis is particularly pertinent in this context: regions with less stringent environmental regulations may attract emission-intensive industries that have been displaced from areas with stricter controls (Dam & Scholtens, 2015; Jiang et al., 2022; Sarkodie & Strezov, 2018). These spatial externalities highlight the importance of regionally coordinated environmental governance and provide a strong rationale for employing spatial econometric models to more accurately evaluate policy effectiveness.

2.4. Research Gaps and This Study's Contribution

While a substantial body of research has examined green taxation and fiscal decentralization as separate phenomena, limited scholarly attention has been given to incorporating multidimensional aspects of fiscal decentralization into the analysis of green taxation and carbon emissions. Much of the existing literature relies on a single aggregate measure of decentralization, thereby overlooking the distinct incentive structures associated with revenue sharing, expenditure responsibilities, and fiscal autonomy. Furthermore, although the existence of spatial spillovers is widely acknowledged, the interactive effects of fiscal decentralization and green taxation within a spatial strategic framework remain

largely underexplored. K. Zhang et al. (2017) demonstrate that fiscal decentralization may undermine the effectiveness of environmental policies; however, the underlying mechanisms—particularly across different dimensions of decentralization—are not yet fully understood or systematically articulated.

This study makes four key contributions: (1) Assessing the direct and spatial spillover effects of green taxation through a spatial econometric framework; (2) Investigating the three distinct dimensions of fiscal decentralization—revenue decentralization, expenditure decentralization, and financial autonomy—and their nonlinear relationships with carbon emissions; (3) Examining how each dimension of fiscal decentralization moderates the impact of green taxes by incorporating interaction terms into the analysis; (4) Providing policy insights that consider both local effects and interregional spillovers.

The primary objective of this study is to examine the spatial effects of green taxation on carbon emissions within the context of China's fiscal decentralization. The specific research objectives are as follows: To quantify the direct and spatial spillover effects of green taxation on carbon emissions. To investigate how different dimensions of fiscal decentralization—specifically revenue decentralization, expenditure decentralization, and financial autonomy—moderate the relationship between green taxation and carbon emissions. To explore the nonlinear impacts of fiscal decentralization on carbon emissions in both local jurisdictions and their neighboring regions. To derive policy implications that are relevant not only for China but also for other developing and transitional economies facing similar environmental and fiscal governance challenges. Drawing upon theoretical expectations and empirical patterns, we further hypothesize that under certain conditions, fiscal decentralization may enhance the effectiveness of green taxation in reducing carbon emissions:

H3a: *A higher degree of fiscal expenditure decentralization enhances the carbon emission reduction effect of green taxation.*

H3b: *A higher degree of fiscal revenue decentralization enhances the carbon emission reduction effect of green taxation.*

H3c: *Greater financial autonomy enhances the carbon emission reduction effect of green taxation.*

3. Methodology

3.1. Characterization of Variables

3.1.1. Explained Variables

The carbon emissions indicator is measured using per capita carbon emissions (pce) (Cheng et al., 2019; Lin & Li, 2011). Given China's status as a major energy-consuming country, where carbon emissions from energy consumption constitute the majority of its total carbon emissions, per capita carbon emissions are calculated as the ratio of carbon emissions from energy consumption to the year-end resident population. The estimation of carbon emissions from energy consumption follows the Guidelines for the Preparation of Provincial Greenhouse Gas Inventories issued by China's National Development and Reform Commission (NDRC) and the Carbon Emission Guidelines provided by the Intergovernmental Panel on Climate Change (IPCC). The formula for calculating carbon dioxide emissions from energy consumption in China is as follows:

$$CE_i = \sum(E_i \times EF_i), \quad (1)$$

$$EF_i = NCV_i \times C_i \times O_i \times \frac{44}{12} \quad (2)$$

where CE_i is the carbon dioxide emissions from energy consumption, measured in tons of CO_2 (tCO_2); EF_i is the carbon emission factor for i-th fossil energy source, calculated based on the H. Hu (2023), the Guidelines for the Preparation of Provincial-level Greenhouse Gas Inventories (Trial), the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and the General Principles for the Calculation of Comprehensive Energy Consumption (National Technical Committee on Energy Foundation and Management of Standardization Administration of China (SAC/TC 20), 2020); E_i is the physical volume of i-th energy consumption, This study accounts for China's energy consumption and carbon emissions using 23 general energy end-use categories, including heat and electricity. The carbon emission factor for heat consumption is set at the officially recommended value of 0.11 tCO_2/GJ in China, while the emission factor for electricity consumption uses the average provincial-level CO_2 emission factor published by the Ministry of Ecology and Environment and the National Bureau of Statistics of China.

3.1.2. Core Explanatory Variables

Green Taxation (ggti): There are three approaches to measuring green taxation: narrow green taxation, medium green taxation, and broad green taxation. Narrow green taxation refers specifically to environmental protection taxes. Medium green taxation includes all taxes and tax items associated with the rational exploitation of resources and effective environmental protection. Broad green taxation, building upon the foundation of medium green taxation, encompasses all tax policies aimed at promoting energy conservation and environmental protection, including preferential tax measures (Deng & Wang, 2013). To comprehensively evaluate the impact of China's green taxation on carbon emissions within the context of fiscal decentralization, and taking into account data availability, this study selects medium green taxation for analysis.

The Green Taxation Index is calculated as $\frac{\sum(\text{green tax})_{i,t}}{\text{tax}_{i,t}}$, representing the ratio of the sum of revenues from eight green-related taxes—specifically, resource tax, environmental protection tax, urban construction and maintenance tax, vehicle, and vessel tax, arable land occupation tax, consumption tax, vehicle purchase tax, and urban land use tax—to the total tax revenue (Deng & Wang, 2013; Fang et al., 2023).

3.1.3. Control Variables

Economic development (pgdp): According to the environmental Kuznets curve hypothesis, sustained economic growth significantly influences both environmental pollution and the emission levels of greenhouse gases such as carbon dioxide. On the one hand, with the continuous development of the regional economy, there is an increasing demand for a better and more livable living environment. To this end, local governments strive to meet these expectations by improving environmental quality and enhancing public service delivery. On the other hand, due to regional development imbalances in China and differences in economic development patterns across regions, some local governments continue to engage in "growth competition" by prioritizing GDP expansion at the expense of environmental protection. This behavior may negatively affect environmental quality and lead to higher CO_2 emissions. Therefore, the per capita regional GDP of each province is adopted as an indicator to characterize the level of regional economic development (Gu & Jiang, 2013; Shi & Wu, 2017).

Urbanization rate (ur): The ratio of the total urban population to the permanent resident population is adopted as the indicator for measuring urbanization (Quan et al., 2024; W. Z. Wang et al., 2021). On the one hand, with the continuous advancement of China's urbanization process, population and industrial agglomeration result in increased resource and energy consumption, higher carbon dioxide emissions, and greater environmental

pressure. At the same time, urbanization may also exert a certain inhibitory effect on carbon emission intensity.

Energy structure (es): Energy consumption is a key production factor that drives economic development, and at the same time, it is also the primary source of carbon emissions. As shown in Table 1, carbon emissions generated by different types of fossil energy vary significantly. Among them, coal has a higher carbon emission factor; therefore, the higher the proportion of coal in energy consumption, the greater the carbon dioxide emissions. China is a major coal-consuming country, with relatively limited use of oil and a slower development of natural gas utilization compared to coal and oil. Coal remains the dominant source of carbon emissions across various regions in China. Since the adjustment of the energy consumption structure requires a long-term process and energy technology levels are difficult to improve rapidly, the current inefficient energy structure imposes significant pressure on China's efforts to reduce carbon emissions. Therefore, this paper selects the ratio of raw coal consumption to total energy consumption as a control variable (Dong et al., 2019; Z. Zhang, 2000).

Table 1. Energy types and carbon emission factors (Unit: tCO_2/T).

Energy Type	Carbon Emission Factors	Energy Type	Carbon Emission Factors
Raw Coal	1.90	Gasoline	292.51
Washed Coking Coal	228.27	Kerosene	303.21
Other Washed Coal	78.90	Diesel	309.59
Coal Products	176.20	Fuel Oil	317.05
Coal Gangue	55.26	Liquefied Petroleum Gas	310.13
Coke	285.27	Refinery Dry Gas	301.19
Coke Oven Gas	763.62	Other Petroleum Products	277.99
Blast Furnace Gas	968.65	Natural Gas	2165.02
Converter Gas	1430.48	Liquefied Natural Gas	2328.35
Other Gas	231.79	gasoline	292.51
Other Coking Products	336.52	kerosene	303.21
Crude Oil	301.72		

Industrial Structure (ind): The degree of regional carbon emissions is closely associated with its industrial structure, which serves as a key mechanism through which human activities influence environmental pollution. With the continuous advancement of industrialization in China, the demand for energy and resources continues to rise. A backward industrial structure hinders the improvement of resource utilization efficiency, while the high-input, high-emission, and high-pollution production model exacerbates environmental pollution and may increase carbon emission intensity. In contrast, upgrading the industrial structure can help eliminate outdated production capacity and enhance the efficiency of resource and energy use, thereby contributing to a reduction in carbon emission intensity. Therefore, industrial structure is selected as a control variable to assess the impact of green taxation on carbon emissions (Chung, 1998; C. Hu & Huang, 2008).

Technological Innovation (tec): R&D investment can, to some extent, reflect the level of production technology in a region. It is generally believed that a higher level of production technology corresponds to a more advanced industrial structure and a higher level of energy utilization, which in turn contributes to the reduction in regional carbon emissions.

Openness to the outside world (ope): In foreign trade, the import and export activities of high-carbon industries have the most significant impact on carbon emissions, particularly in developing countries. Increased openness may generate technology spillovers in China and promote the transformation and upgrading of local firms through the "competition effect,"

thereby enhancing market competitiveness and encouraging the adoption of green production methods, which ultimately leads to a reduction in carbon emission intensity. At the same time, frequent occurrences of carbon leakage in foreign trade also significantly affect China's carbon emissions. Therefore, the ratio of total goods imports and exports to GDP is used as an indicator to represent foreign trade (Ertugrul et al., 2016; Michieka et al., 2013).

Infrastructure (ti): Firstly, due to the "lock-in effect" of capital expenditure, the scale and type of infrastructure are directly shaped by the financial incentives and evaluation mechanisms of local governments. Secondly, infrastructure can generate "induced demand" by altering the relative prices of production factors and agglomeration patterns, thereby influencing energy consumption patterns. Finally, the "spatial reconstruction" function of infrastructure may lead to inter-regional industrial and pollution transfers, resulting in spatial spillover effects. These effects are closely linked to the competitive behavior of local governments under fiscal decentralization. The ratio of highway mileage to the permanent resident population is used as an indicator to measure the level of infrastructure development (Muller et al., 2013; Xie et al., 2017).

3.1.4. Moderating Variables

We measure fiscal decentralization following the method of S. Chen and Gao (2012). Fiscal decentralization (fd): three calibers are used to measure fiscal decentralization, namely fiscal revenue decentralization (fdsr), fiscal expenditure decentralization (fdse), and local financial autonomy (fdsz), and to diminish the influence of government expenditure, revenue size, and population in measuring the degree of decentralization of local governments, the fiscal decentralization indicator is per capitalized.

$$\begin{aligned}&\text{Fiscal Revenue Decentralization (fdsr)} = \\ &\qquad (\text{Provincial per capita fiscal revenue})/ \\ &(\text{Provincial per capita fiscal revenue} + \text{Per capita Central Government fiscal revenue})\end{aligned} \tag{3}$$

$$\begin{aligned}&\text{Fiscal Expenditure Decentralization (fdse)} = \\ &\qquad (\text{Provincia1 Per Capita Fiscal Expenditure})/ \\ &(\text{Provincia Per capita fiscal expenditure} + \text{Per capita Central Government fiscal expenditure})\end{aligned} \tag{4}$$

$$\begin{aligned}&\text{Fiscal Autonomy (fdsz)} = \\ &\qquad (\text{Provincial per capita fiscal revenue})/ \\ &\qquad (\text{Provincia Per capita fiscal expenditure})\end{aligned} \tag{5}$$

3.1.5. Spatial Weight Matrices

Common spatial weight matrices include the neighborhood spatial weight matrix, geographic distance spatial weight matrix, economic distance spatial weight matrix, and geographic-economic nested spatial weight matrix. In this study, we select the neighborhood spatial weight matrix and the geographic distance spatial weight matrix based on the research content.

(1) Neighborhood Weight Matrix

The latitude, longitude, and boundaries of Chinese provinces, municipalities, and autonomous regions are extracted from the standard map of China obtained from DataV data visualization. Based on this information, an adjacency geospatial weight matrix W1 is constructed, which is defined as follows:

$$W1 = \begin{cases} 1, & \text{Region i is adjacent to region j, } i \neq j \\ 0, & \text{Region i is not adjacent to region j, } i \neq j \\ 0, & i = j \end{cases}. \tag{6}$$

In this study, the neighborhood relationship between regions is defined based on adjacency. Specifically, the elements of the adjacency matrix W1 are assigned a value of 1 if regions i and j share a common boundary; otherwise, they are assigned a value of 0. To ensure the reliability of our results, we follow the precedent set by previous scholars and designate Guangdong Province as the immediate neighbor of Hainan Province.

(2) Geographic distance spatial weighting matrix

The latitude and longitude coordinates of Chinese provinces and autonomous regions are extracted from the standard map of China obtained from DataV data visualization to construct the geographic distance matrix W2, which is defined as follows:

$$W2 = \begin{cases} 1/d^2, i \neq j \\ 0, i = j \end{cases}, \quad (7)$$

where d is the distance between the locations of the geographic centers of the two regions.

3.1.6. Data Source and Descriptions

Table 2 presents the core variables constructed for the empirical analysis of the interplay between fiscal decentralization, green taxation, and carbon emissions. All indicators are rigorously derived from official statistical yearbooks. The data sources, primarily drawn from national and provincial-level statistical publications, ensure the reliability and panel consistency of the metrics used in the spatial econometric estimation.

Table 2. Data source.

Variable	Variable Definitions	Data Source
lnpce	The ratio of CO_2 emissions from energy consumption to the year-end resident population	China Energy Statistical Yearbook (2008–2023)
ggti	Environmental protection tax, resource tax, vehicle and vessel tax, urban construction and maintenance tax, urban land use tax, cultivated land occupation tax, consumption tax, and vehicle purchase tax, expressed as a proportion of total tax revenue.	China Tax Statistics Yearbook (2008–2023)
pgdp	The ratio of gross regional product to the average annual population	China Statistical Yearbook (2008–2023)
ur	The ratio of the total urban population to the number of permanent residents	
es	Proportion of Raw Coal Consumption in Total Energy Consumption	China Energy Statistical Yearbook (2008–2023)
ind	The ratio of the added value of the secondary industry to GDP	EPS Database and China Statistical Yearbook (2008–2023)
ope	The ratio of total goods imports and exports to GDP	
tec	The ratio of R&D expenditure to GDP	
ti	The ratio of highway mileage to the permanent resident population	
fdsr	Ratio of Provincial Per Capita Fiscal Revenue to Per Capita Central Government Fiscal Revenue	China Finance Yearbook (2008–2023)
fdse	Ratio of Provincial Per Capita Fiscal Expenditure to Per Capita Central Government Fiscal Expenditure	
fdsz	Ratio of Provincial Per Capita Fiscal Revenue to Per Capita Central Government Fiscal Expenditure	

Descriptive statistics for each variable are presented in Table 3. China's carbon emissions remain at a relatively high level, with notable regional disparities. Green tax revenues are generally low, and there are substantial inter-provincial variations. Economic development levels exhibit significant heterogeneity, ranging from a minimum of 0.778 to a maximum of 19.031. Urbanization levels are moderate, with variation across provinces. The energy structure is dominated by high-carbon sources, indicating a relatively high reliance on carbon-intensive energy. The proportion of secondary industries is generally high, though inter-provincial differences are minimal. Regional openness varies considerably. Overall, science and technology investments remain low, with limited variation among provinces. Infrastructure development is unevenly distributed across regions. Fiscal revenue decentralization is at a moderate level, with provincial values relatively concentrated. Fiscal expenditure decentralization is relatively high, with small inter-provincial differences. Fiscal autonomy is at a moderate level, showing some regional variation.

Table 3. Statistical descriptions of primary variables.

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
lnpce	Per capita carbon emissions	480	1.915	0.505	0.717	3.375
ggti	Green taxation	480	0.430	0.168	0.123	1.118
pgdp	Per capita GDP (Economic development)	480	5.050	3.090	0.778	19.031
ur	Urbanization rate	480	0.558	0.139	0.275	0.938
es	Energy Structure	480	0.681	0.164	0.004	0.937
ind	Industrial Structure	480	0.437	0.088	0.158	0.590
ope	Technological Innovation	480	0.285	0.303	0.007	1.667
tec	Openness to the outside world	480	0.017	0.011	0.002	0.068
ti	Infrastructure	480	0.378	0.236	0.051	1.474
fdsr	fiscal revenue decentralization	480	0.499	0.129	0.263	0.833
fdse	fiscal expenditure decentralization	480	0.846	0.050	0.698	0.938
fdsz	local financial autonomy	480	0.496	0.193	0.148	0.951

3.1.7. Model Design

Modeling carbon emissions exhibits strong spatial correlation and negative externality. This spatial correlation arises from two primary mechanisms: spillover effects and localized regional externalities. These mechanisms imply that carbon emissions are influenced not only by local variables but also by the surrounding environment. Consequently, general static regression models cannot accurately capture these spatial characteristics. Therefore, we opt for the spatial Durbin model (SDM) to address this issue. The SDM is capable of providing unbiased estimates and resolving endogeneity problems associated with variables. In this study, the spatial Durbin model is employed to construct the subsequent model:

$$\ln pce_{i,t} = \alpha_1 + \rho_1 w \ln pce_{i,t} + \beta_1 ggti_{i,t} + \beta_2 fd_{i,t} + \beta_3 fd^2{}_{i,t} + \beta_4 X_{i,t} + w\beta_5 ggti_{i,t} + w\beta_6 fd_{i,t} + w\beta_7 fd^2{}_{i,t} + w\beta_8 X_{i,t} + \mu_i + \varphi_t + \varepsilon_i, \quad (8)$$

$$\ln pce_{i,t} = \alpha_2 + \rho_2 w \ln pce_{i,t} + \beta_2 fd_{i,t} + \beta_3 (fd_{i,t} \times pgdp_{i,t}) + \beta_4 pgdp_{i,t} + \beta_5 X_{i,t} + w\beta_6 ggti_{i,t} + w\beta_7 fd_{i,t} + w\beta_8 (fd_{i,t} \times pgdp_{i,t}) + w\beta_9 pgdp_{i,t} + w\beta_{10} X_{i,t} + \mu_i + \varphi_t + \varepsilon_i, \quad (9)$$

$$\ln pce_{i,t} = \alpha_3 + \rho_3 w \ln pce_{i,t} + \beta_1 ggti_{i,t} + \beta_2 \left(ggti_{i,t} \times fd_{i,t} \right) + \beta_3 fd_{i,t} + \beta_4 fd^2{}_{i,t} + \beta_5 X_{i,t} + w\beta_6 ggti_{i,t} + w\beta_7 \left(ggti_{i,t} \times fd_{i,t} \right) + w\beta_8 fd_{i,t} + w\beta_9 fd^2{}_{i,t} + w\beta_9 X_{i,t} + \mu_i + \varphi_t + \varepsilon_i, \quad (10)$$

where i and t refer to the i th province, city, autonomous region, and year t, respectively; lnpce is the logarithm of per capita carbon emissions; ρ, δ, β, and λ are the regression

coefficients to be estimated; μ and ε represent the residual terms of the spatial and temporal specific effects, respectively; and ε is a generalized term for the control variables.

4. Result

4.1. Spatial Correlation Analysis

Before conducting a spatial empirical analysis, it is crucial to verify the spatial correlation of carbon emissions across geographies. As shown in Table 4, under both spatial weight matrices, the global Moran's I index and the global Geary's C index for carbon emissions are significantly greater than zero and pass the 1% significance test. This indicates that carbon emissions exhibit significant spatial correlation, justifying the use of spatial econometric models for analysis.

Table 4. Global Moran's index and Geary's index for carbon emissions, 2007–2022.

Matrix	W1				W2			
Year	Moran's I	*p*-Value	Geary's c	*p*-Value	Moran's I	*p*-Value	Geary's c	*p*-Value
2007	0.466	0.000	0.487	0.000	0.188	0.000	0.794	0.000
2008	0.458	0.000	0.511	0.000	0.177	0.000	0.802	0.000
2009	0.451	0.000	0.532	0.000	0.170	0.000	0.806	0.000
2010	0.472	0.000	0.525	0.000	0.162	0.000	0.811	0.000
2011	0.454	0.000	0.577	0.001	0.147	0.000	0.823	0.000
2012	0.456	0.000	0.561	0.001	0.147	0.000	0.818	0.000
2013	0.497	0.000	0.504	0.000	0.152	0.000	0.804	0.000
2014	0.477	0.000	0.521	0.000	0.142	0.000	0.808	0.000
2015	0.459	0.000	0.540	0.000	0.137	0.000	0.810	0.000
2016	0.504	0.000	0.544	0.001	0.140	0.000	0.799	0.000
2017	0.411	0.000	0.579	0.002	0.117	0.000	0.823	0.000
2018	0.433	0.000	0.604	0.003	0.128	0.000	0.823	0.000
2019	0.412	0.000	0.621	0.004	0.122	0.000	0.831	0.000
2020	0.425	0.000	0.614	0.004	0.121	0.000	0.830	0.000
2021	0.423	0.000	0.598	0.003	0.119	0.000	0.824	0.000
2022	0.409	0.000	0.609	0.004	0.114	0.000	0.829	0.000

The results of local spatial autocorrelation (Local Moran's I) in Table 5 provide an empirical basis for the construction of the Spatial Durbin Model (SDM). Provinces in western China, such as Yunnan and Sichuan, are identified as "low–low" or "high–high" clusters, indicating the necessity to introduce a spatial lag term in subsequent analysis to capture spatial spillover effects.

Table 5. Local Moran's index for per capita carbon emissions.

Province	W1				W2			
	Moran's Ii of 2007		Moran's Ii of 2022		Moran's Ii of 2007		Moran's Ii of 2022	
	Ii	Quadrant	Ii	Quadrant	Ii	Quadrant	Ii	Quadrant
Beijing	1.423	1	−0.539	2	0.677	1	−0.275	2
Tianjin	1.701	1	0.279	1	0.772	1	0.126	1
Hebei	0.997	1	0.724	1	0.453	1	0.311	1
Shanxi	0.506	1	0.821	1	0.392	1	0.333	1
Inner Mongolia	0.745	1	1.470	1	0.488	1	0.515	1
Liaoning	1.019	1	1.017	1	0.278	1	0.090	1
Jilin	0.349	1	−0.405	2	0.121	1	−0.093	2
Heilongjiang	−0.241	2	−0.014	2	−0.081	2	−0.002	2
Shanghai	0.641	1	0.052	1	0.031	1	0.003	1

Table 5. *Cont.*

Province	W1				W2			
	Moran's Ii of 2007		Moran's Ii of 2022		Moran's Ii of 2007		Moran's Ii of 2022	
	Ii	Quadrant	Ii	Quadrant	Ii	Quadrant	Ii	Quadrant
Jiangsu	0.174	1	0.067	1	−0.017	4	−0.040	4
Zhejiang	−0.077	4	−0.021	4	0.058	1	−0.004	4
Anhui	0.103	3	0.058	3	−0.132	2	−0.012	2
Fujian	0.153	3	0.084	3	0.031	3	0.024	3
Jiangxi	0.571	3	0.361	3	0.129	3	0.130	3
Shandong	0.012	1	0.057	1	0.235	1	0.110	1
Henan	−0.049	2	−0.256	2	−0.050	2	−0.132	2
Hubei	0.269	3	0.366	3	0.060	3	0.093	3
Hunan	0.492	3	0.716	3	0.154	3	0.200	3
Guangdong	0.315	3	0.662	3	0.098	3	0.246	3
Guangxi	0.793	3	0.623	3	0.424	3	0.230	3
Hainan	0.460	3	1.024	3	0.432	3	0.314	3
Chongqing	0.651	3	0.657	3	0.266	3	0.244	3
Sichuan	1.096	3	0.833	3	0.312	3	0.240	3
Guizhou	0.428	3	0.889	3	0.147	3	0.277	3
Yunnan	1.378	3	1.412	3	0.342	3	0.341	3
Shaanxi	−0.052	2	0.039	1	−0.028	2	0.005	1
Gansu	−0.064	2	−0.264	2	−0.015	2	−0.062	2
Qinghai	0.148	3	−0.031	4	0.008	3	0.010	1
Ningxia	0.217	1	1.704	1	0.053	1	0.166	1
Xinjiang	−0.176	4	−0.113	4	0.006	1	0.036	1

4.2. Model Selection and Evaluation

Before conducting the analysis of spatial effects, it is essential to test and select an appropriate spatial regression model. The results of the preliminary tests are presented in Table 6. The values of LM-error, LM-lag, and R-LM-lag are all statistically significant, indicating that the spatial Durbin model can be considered as a suitable specification. However, we observe that the R-LM-lag values are not significant in some cases. To ensure the validity of selecting the spatial Durbin model, a likelihood ratio (LR) test is conducted. The LR test results reject the null hypothesis at the 1% significance level, further supporting the appropriateness of the spatial Durbin model. Additionally, the Wald test confirms that the spatial Durbin model does not degenerate into either the spatial autoregressive model or the spatial error model.

Table 6. Test results for the applicability of SDM.

Test	W1			W2		
	fdsr	fdse	fdsz	fdsr	fdse	fdsz
LM-error	120.636 ***	151.028 ***	147.387 ***	120.636 ***	151.028 ***	147.387 ***
R-LM-error	100.436 ***	130.690 ***	136.310 ***	100.436 ***	130.690 ***	136.310 ***
LM-lag	21.849 ***	20.934 ***	11.422 ***	21.849 ***	20.934 ***	11.422 ***
R-LM-lag	1.650	0.596	0.345	1.650	0.596	0.345
Hausman test	3168.51 ***	27.99 ***	34.27 ***	117.29 ***	67.57 ***	94.03 ***
lrtest both ind	58.52 ***	24.54 ***	81.02 ***	62.84 ***	53.38 ***	78.39 ***
lrtest both time	1065.86 ***	1113.22 ***	1090.63 ***	1084.20 ***	1106.04 ***	1135.71 ***
Wald Test for SAR	49.05 ***	39.28 ***	42.21 ***	64.47 ***	61.31 ***	74.28 ***
Wald Test for SEM	48.69 ***	40.21 ***	43.87 ***	64.57 ***	65.40 ***	74.81 ***
LR test for SAR	46.57 ***	37.75 ***	40.48 ***	59.56 ***	57.60 ***	68.35 ***
LR test for SEM	46.82 ***	38.88 ***	42.33 ***	55.64 ***	57.78 ***	65.95 ***

Note: *** $p < 0.01$.

Given that the dataset consists of panel data, it is also necessary to determine whether a fixed-effects or random-effects specification should be adopted, even after accounting for spatial dependencies through spatial econometric techniques.

4.3. Analysis of the Spatial Spillover Effect of Tax Greenness on Carbon Emissions

According to Table 7, green taxation is positively correlated with local environmental pollution (Main), reflecting the "green paradox" phenomenon in China's current green taxation system. Under the pressure of economic growth and the official evaluation system—for example, the GDP growth rate remains a key performance indicator—local governments may encourage or rely on industries with high pollution and high energy consumption to sustain high economic growth, thereby offsetting the carbon emission reduction effect of green taxation. However, in neighboring regions (Wx), green taxation is negatively correlated with per capita carbon emissions, suggesting that green taxation may generate positive spillover effects at the interregional level, potentially promoting the relocation of polluting enterprises or facilitating technology diffusion.

Table 7. Spatial Durbin model regression results on the impact of green taxation on regional carbon emissions under multidimensional fiscal decentralization.

Variable	W1					
	Main	**Wx**	**Main**	**Wx**	**Main**	**Wx**
ggti	0.392 *** (5.19)	−0.417 *** (−2.68)	0.397 *** (5.17)	−0.472 *** (-3.03)	0.363 *** (4.74)	−0.471 *** (−2.94)
fdsr	−0.911 (−1.34)	5.042 *** (3.97)				
$fdsr^2$	1.560 ** (2.34)	−3.697 *** (−2.85)				
fdse			0.114 (0.20)	−0.365 (−0.35)		
$fdse^2$			0.724 *** (2.74)	1.548 *** (2.81)		
fdsz					0.917 ** (2.33)	2.026 ** (2.59)
$fdsz^2$					−0.753 ** (−2.32)	−1.529 ** (−2.48)
pgdp	−0.012 (−1.61)	0.022 (1.35)	−0.005 (−0.59)	0.007 (0.42)	-0.009 (−1.17)	0.006 (0.37)
Spatial rho	−0.150 ** (−2.29)		−0.146 ** (−2.23)		−0.134 ** (−2.05)	
Control Variable	Yes					
Time	Yes					
Space	Yes					
Variance sigma2_e	0.006 *** (15.45)		0.006 *** (15.45)		0.007 *** (15.46)	
N	480		480		480	
Log-likelihood	536.0805		529.8160		523.6321	

Note: ** $p < 0.05$, *** $p < 0.01$.

Within provinces, there exists an insignificant yet significantly negative U-shaped relationship between revenue decentralization (fdsr) and carbon emissions. This suggests that in the initial stage, the expansion of local fiscal revenue autonomy may slightly reduce carbon emissions by allocating funds toward environmental investments. However, once the degree of decentralization surpasses a certain inflection point, it tends to exacerbate

carbon emissions. This strongly supports China's "local competition" model. Under the economic growth-centered evaluation system, when local governments gain greater control over fiscal revenues, their focus tends to shift toward "hard" infrastructure and heavy chemical projects that can rapidly boost GDP, rather than "soft" environmental governance, which involves long cycles and delayed outcomes. As fiscal autonomy increases, local governments are more inclined to use financial resources for high-intensity investment competition and may even attract enterprises by lowering environmental access thresholds, resulting in increased carbon emissions. For surrounding regions, the fiscal revenue decentralization of a given province exhibits a significant "inverted U-shaped" effect. When the level of local fiscal decentralization increases, it initially imposes a strong negative spillover effect—manifested as increased carbon emissions—on neighboring provinces. However, beyond a certain threshold, this negative impact diminishes. This pattern reveals both the "pollution haven" effect and the "race to the bottom" mechanism. When a province gains more fiscal autonomy and actively attracts investment, its lax environmental policy may attract polluting firms from neighboring regions with stricter environmental standards, thereby increasing carbon emissions in surrounding areas in the short run.

Fiscal expenditure decentralization (fdse) exhibits a significant positive U-shaped relationship within the region. The initial effect is not pronounced, but once the inflection point is surpassed, higher levels of expenditure decentralization correspond to increased local carbon emissions. This follows a logic similar to that of revenue decentralization, but with greater emphasis on expenditure structure. Chinese local governments demonstrate a strong preference for "productive expenditure," prioritizing spending on economic construction, energy, and transportation over public services and environmental protection. This tendency intensifies with the expansion of spending autonomy, as funds are increasingly directed toward projects that generate short-term economic growth. Consequently, environmental expenditures are crowded out, resulting in higher carbon emissions. This pattern of expenditure structure is closely associated with China's development stage and was more prevalent during the period of rapid industrialization and urbanization. The effect on surrounding areas is again "U-shaped," but the main term is negative (insignificant). This suggests that when a province increases expenditure decentralization, it may initially produce weak positive spillovers on the carbon emissions of neighboring regions—through cross-regional infrastructure investment or green technology R&D. However, significant negative spillovers tend to emerge in later stages, and these negative effects may dominate. By heavily investing in industrial park construction and offering subsidies, local governments may create "policy depressions" that attract high-quality enterprises and resources from surrounding areas. This compels neighboring regions to adopt more aggressive development strategies that increase carbon emissions in order to sustain economic growth, ultimately leading to a cycle of vicious competition.

Fiscal autonomy (fdsz) exhibits a clear inverted U-shaped relationship. It indicates that as a province's fiscal autonomy increases, carbon emissions initially worsen and subsequently improve. This reflects the evolution of China's development stage and governance capacity. In the early stage—before the inflection point—local governments expanded their financial resources but held outdated development concepts, leading to a prioritization of economic growth at the expense of environmental protection and, consequently, rising carbon emissions. However, once the economic level reaches a certain threshold, increasing pressure from central environmental assessments and growing public awareness of environmental protection prompt financially capable local governments to invest more in environmental governance. They also begin promoting industrial transformation and upgrading, thereby reducing carbon emissions. This represents a typical developmental trajectory shifting from "pollution first" to "governance later." It also exhibits an inverted

U-shaped impact on surrounding areas, but the initial term is positive, indicating that the enhancement of provincial fiscal autonomy generates a strong negative spillover on the carbon emissions of neighboring regions in the early stage. This mechanism is similar to that of fdsr. When a province's financial capacity improves, it may attract industries and investment from surrounding areas through more favorable policies during the initial phase. This disrupts the development trajectory of neighboring regions and may compel them to rely on resource extraction or polluting industries, thereby increasing carbon emissions. However, once the province surpasses the inflection point and begins industrial upgrading and stricter enforcement of environmental regulations, it may gradually transfer some low-end industries to surrounding areas in a gradient manner.

The spatial rho coefficient is negative and statistically significant (−0.150, −0.146, −0.134**). This negative spatial autocorrelation suggests the presence of "alternative competition" or a "differentiation strategy" in the environmental performance among neighboring provinces.

The results in Table 7 are based on maximum likelihood estimation using neighboring spatial weight matrices. To further verify the robustness of the model estimation results, we conducted spatial Durbin model estimations with alternative spatial weight matrices. The results, presented in Table 8, are consistent with those derived from Table 7, confirming the robustness and credibility of the regression results.

Table 8. Robustness test results.

Variable	W2					
	Main	**Wx**	**Main**	**Wx**	**Main**	**Wx**
ggti	0.284 *** (3.99)	−1.606 *** (−2.88)	0.298 *** (4.10)	−1.715 *** (−3.03)	0.282 *** (3.93)	−1.184 ** (−2.02)
fdsr	−1.108 (−1.63)	8.643 * (1.8)				
$fdsr^2$	1.875 *** (2.84)	−5.619 (−1.21)				
fdse			0.436 (0.82)	−2.622 (−0.91)		
$fdse^2$			0.938 *** (3.84)	2.913 * (1.87)		
fdsz					0.738 ** (2.01)	6.121 *** (2.82)
$fdsz^2$					−0.605 ** (−1.97)	−5.283 *** (−3.02)
pgdp	−0.005 (−0.58)	0.187 *** (3.83)	0.001 (0.13)	0.154 *** (3.33)	−0.006 (−0.83)	0.136 *** (2.82)
Control Variable	Yes					
Time	Yes					
Space	Yes					
Spatial rho	−1.019 *** (−4.71)		−1.019 *** (−4.68)		−1.034 *** (−4.90)	
Variance sigma2_e	0.006 *** (15.04)		0.006 *** (15.02)		0.006 *** (15.07)	
N	480		480		480	
Log-likelihood	553.7261		549.4224		546.0153	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

According to the results in Table 9, the results across the three models are highly consistent, revealing a clear yet paradoxical pattern: the direct effect is significantly positive (approximately 0.4), which further confirms the previously observed "paradox." Indirect effect: it is significantly negative (approximately −0.45), representing a critically important finding. This indicates that an increase in green taxation within a region exerts a significant inhibitory effect on carbon emissions in neighboring regions—referred to as a negative spillover effect. This phenomenon may arise because stringent local pollution controls prompt firms to adopt higher environmental standards, with technological or policy innovations spilling over into neighboring areas, thereby reducing cross-regional carbon emissions. Total effect (Total): negative but statistically insignificant. After the direct effect (emission increase) and indirect effect (emission reduction) offset each other, the overall impact of green taxation on emissions across the entire region becomes statistically insignificant. This suggests that while the net effect is not clearly discernible from a global average perspective, green taxation significantly alters the spatial distribution of emissions. The primary impact of green taxation lies in its spatial spillover effect, rather than in directly reducing local emissions.

Table 9. Decomposition of spatial spillover effects of green taxes on regional carbon emissions under multi-dimensional fiscal decentralization.

Variable	W1								
	Direct	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
ggti	0.411 ***	−0.434 ***	−0.023	0.417 ***	−0.485 ***	−0.067	0.382 ***	−0.481 ***	−0.099
	(5.26)	(−3.15)	(−0.16)	(5.26)	(−3.47)	(−0.45)	(4.83)	(−3.39)	(−0.65)
fdsr	−1.117 *	4.754 ***	3.637 ***						
	(−1.68)	(3.93)	(3.05)						
$fdsr^2$	1.742 ***	−3.645 ***	−1.903						
	(2.67)	(−3.06)	(−1.59)						
fdse				0.099	−0.267	−0.167			
				(0.17)	(−0.26)	(−0.18)			
$fdse^2$				0.705 ***	1.257 **	1.962 ***			
				(2.66)	(2.55)	(4.38)			
fdsz							0.842 **	1.795 **	2.637 ***
							(2.17)	(2.34)	(3.78)
$fdsz^2$							−0.685 **	−1.356 **	−2.041 ***
							(−2.14)	(−2.29)	(−3.81)
pgdp	−0.013 *	0.022	0.008	−0.005	0.007	0.002	−0.009	0.007	−0.003
	(−1.74)	(1.47)	(0.59)	(−0.64)	(0.46)	(0.13)	(−1.21)	(0.44)	(−0.18)
Control Variable	Yes								

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The moderating effect of the interaction between the level of economic development and fiscal decentralization is introduced to explain how the emission reduction effect of fiscal decentralization varies with the level of economic development. As shown in Table 10, the coefficients of the three interaction terms on the local effect are significantly negative, indicating that economic development weakens the positive impact of fiscal decentralization on regional carbon emissions. In terms of the spatial spillover effect, the coefficients of the three interaction terms are all significantly positive, suggesting that economic development also mitigates the effect of fiscal decentralization in increasing carbon emissions in neighboring areas.

Table 10. Impact of multidimensional fiscal decentralization and economic growth on carbon emissions.

Variable	W1					
	Main	**Wx**	**Main**	**Wx**	**Main**	**Wx**
fdsr	0.850 *** (4.12)	1.044 ** (2.37)	1.751 *** (3.99)	0.530 (0.64)	0.438 ** (2.30)	−0.254 (−0.82)
pgdp	0.029 (1.28)	−0.156 *** (−3.75)	0.193 *** (2.85)	−0.611 *** (−4.39)	0.046 ** (2.23)	−0.039 (−1.22)
fdsr × pgdp	−0.048 * (−1.82)	0.221 *** (4.39)				
fdse × pgdp			−0.211 *** (−2.92)	0.695 *** (4.58)		
fdsz × pgdp					−0.061 ** (−2.38)	0.114 *** (2.63)
Control Variable	Yes					
Time	Yes					
Space	Yes					
Spatial rho	−0.209 *** (−3.14)		−0.151 ** (−2.31)		0.204 *** (3.75)	
Variance sigma2_e	0.007 *** (15.42)		0.007 *** (15.45)		0.008 *** (15.43)	
Log-likelihood	523.418		516.016		505.410	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

This result reflects the challenge of carbon emission reduction under China's unbalanced regional development. Specifically, developed regions (such as Beijing, Shanghai, Jiangsu, and Zhejiang, which have higher per capital GDP) have crossed the inflection point of the Environmental Kuznets Curve and place greater emphasis on green and low-carbon development. In the process of development, these regions may transfer carbon emission pressures to surrounding less developed areas through mechanisms such as industrial relocation and investment competition. Meanwhile, to achieve political performance goals such as "sustained growth" and "stable employment," economically underdeveloped regions are more inclined to relax environmental regulations to attract the transfer of high-carbon industries from neighboring developed regions, thereby falling into the trap of "pollution haven." This dynamic leads to a spatial pattern in which carbon emissions decrease in developed regions while increasing in surrounding less developed areas, which is highly consistent with the negative spatial rho.

According to the results in Table 11, decomposing the spatial effects of the three dimensions of fiscal decentralization and economic growth on carbon emissions, the results of the direct effects of fiscal revenue decentralization and fiscal expenditure decentralization are consistent with the regression results of the spatial Durbin model. Regarding spatial spillover effects, a higher level of economic development in neighboring provinces strengthens the promoting effect of fiscal revenue decentralization and fiscal expenditure decentralization on local carbon emissions within the region. Under the dimension of fiscal autonomy, the interaction term between fiscal decentralization and per capita PGDP is not significant, indicating that the level of economic development in neighboring provinces does not moderate the relationship between fiscal autonomy and carbon emissions in the region.

Table 11. Decomposition of spatial effects of multidimensional fiscal decentralization and economic growth on carbon emissions.

Variable	Direct			Indirect			Total		
fdsr	0.817 *** (3.67)	1.758 *** (3.80)	0.436 ** (2.28)	0.758 * (1.9)	0.247 (0.32)	−0.196 (−0.52)	1.574 *** (4.50)	2.005 *** (2.83)	0.241 (0.62)
pgdp	0.036 (1.60)	0.213 *** (3.17)	0.044 ** (2.24)	−0.143 *** (−3.87)	−0.582 *** (−4.56)	−0.036 ** (−1.00)	−0.106 *** (−3.09)	−0.369 *** (−3.03)	0.008 (0.22)
fdsr × pgdp	−0.058 ** (−2.17)			0.204 *** (4.42)			0.146 *** (3.45)		
fdse × pgdp		−0.233 *** (−3.23)			0.662 *** (4.71)			0.428 *** (3.22)	
fdsz × pgdp			−0.055 ** (−2.21)			0.124 (2.40)			0.069 (1.24)
Control Variable	Yes								

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results in Table 12 address the central research question of this paper: whether China's current institutional framework of fiscal decentralization enhances or weakens the impact of green taxation on carbon emissions. The direct effect of the Green Government Tax Revenue Index (ggti) is significantly positive across all three models. This indicates that under China's current fiscal and taxation system, although green taxation serves as an important policy tool, it does not effectively reduce regional carbon emissions and is instead positively correlated with them. This suggests that local governments primarily perceive green taxation as a source of fiscal revenue rather than as a regulatory mechanism for curbing carbon emissions.

Table 12. Effect of multidimensional fiscal decentralization on carbon emissions due to green tax interaction terms.

Variable	W1					
	Main	Wx	Main	Wx	Main	Wx
ggti	0.529 *** (2.72)	−0.981 *** (−2.83)	1.864 ** (2.53)	−4.443 ** (−2.52)	0.485 *** (2.99)	−0.196 (−0.69)
fdsr × ggti	−0.340 (−0.80)	1.540 * (1.82)				
fdsr	−0.750 (−1.01)	4.391 *** (3.31)				
fdsr2	1.558 ** (2.29)	−3.563 *** (−2.75)				
fdse × ggti			−1.798 ** (−2.07)	4.808 ** (2.3)		
fdse			0.734 (1.10)	−1.813 (−1.51)		
fdse2			0.735 *** (2.81)	1.519 *** (2.79)		
fdsz × ggti					−0.354 (−0.93)	−0.977 (−1.31)
fdsz					1.248 ** (2.47)	2.984 *** (2.87)
fdsz2					−0.930 ** (−2.58)	−2.011 *** (−2.86)
pgdp	−0.011 (−1.46)	0.017 (1.07)	−0.005 (−0.66)	0.005 (0.31)	−0.011 (−1.35)	0.006 (0.35)

Table 12. *Cont.*

Variable	W1					
	Main	**Wx**	**Main**	**Wx**	**Main**	**Wx**
ur	−0.245 (−1.6)	−0.608 *** (−2.78)	−0.251 (−1.64)	−0.580 *** (−2.64)	−0.215 (−1.34)	−0.531 ** (−2.36)
es	0.988 *** (9.34)	−0.071 (−0.29)	1.015 *** (9.71)	−0.151 (−0.65)	1.048 *** (9.56)	0.103 (0.43)
ind	0.358 ** (2.09)	−1.103 *** (−2.99)	0.256 (1.49)	−1.202 *** (−3.08)	0.471 *** (2.84)	−0.428 (−1.28)
ope	0.162 ** (2.27)	−0.313 *** (−2.91)	0.151 ** (2.11)	−0.236 ** (−2.24)	0.284 *** (3.93)	−0.069 (−0.55)
tec	−3.603 * (−1.72)	−1.396 (−0.33)	−2.427 (−1.19)	−6.586 * (−1.66)	−1.334 (−0.64)	−4.189 (−0.98)
ti	0.485 *** (3.89)	0.437 *** (1.66)	0.466 *** (3.63)	0.245 (0.85)	0.560 *** (4.33)	0.635 ** (2.22)
Time	Yes					
Space	Yes					
Spatial rho	−0.143 ** (−2.18)		−0.128 * (−1.96)		−0.144 ** (−2.20)	
Variance sigma2_e	0.006 *** (15.46)		0.006 *** (15.46)		0.007 *** (15.46)	
N	480		480		480	
Log-likelihood	537.9265		536.1795		524.9152	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

With regard to the moderating effect of fiscal decentralization, we examine both the statistical significance and the direction of the interaction terms between fiscal decentralization and green taxation. The findings reveal that fiscal expenditure decentralization (fdse) has the weakest moderating effect, whereas fiscal revenue decentralization (fdsr) and fiscal autonomy (fdsz) exhibit significant moderating effects. This implies that local governments are more responsive to the sources of fiscal revenue than to how it is allocated, which aligns with fiscal incentive theory. The overall effect of fiscal autonomy is negative, suggesting that increased local fiscal self-sufficiency can, to some extent, enhance the emission-reduction effectiveness of green taxation.

Table 13 presents the spatial effect decomposition of Table 12, accurately distinguishing the influence of interaction terms into direct, indirect, and total effects. The results confirm the interaction effect between fiscal decentralization and green taxation. Moreover, the spatial phenomenon in which local and surrounding area effects offset or even contradict each other contributes to the uncertainty and divergence in the overall effect.

The decomposition results of the interaction term for fiscal revenue decentralization reveal that green taxation, under the influence of fiscal revenue decentralization, increases carbon emissions overall. This is primarily due to intensified tax competition among local governments under fiscal revenue decentralization, whereby the strict enforcement of green taxes locally may drive high-carbon-emission enterprises to neighboring regions.

The interaction term for fiscal expenditure decentralization exhibits a contradictory pattern: the local effect is negative, indicating that local governments can reduce local carbon emissions by allocating green tax revenues to specific environmental purposes and emission control initiatives. However, this may simultaneously increase emissions in surrounding areas, effectively shifting the carbon emission problem across space.

The spatial effect decomposition of the interaction term for fiscal autonomy indicates that when local governments possess sufficient financial resources and greater fiscal self-sufficiency, their fiscal interests become more aligned with long-term carbon reduction goals.

Table 13. Decomposition of spatial effects of multidimensional fiscal decentralization on carbon emissions due to the green tax interaction term.

Variable	W1								
	Direct	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
ggti	0.568 *** (2.82)	−0.935 *** (−2.77)	−0.367 (−1.02)	2.022 *** (2.72)	−4.179 ** (−2.53)	−2.157 (−1.12)	0.499 *** (2.94)	−0.221 (−0.79)	0.278 (0.99)
fdsr × ggti	−0.409 (−0.92)	1.375 * (1.77)	0.966 (1.17)						
fdsr	−0.816 (−1.13)	4.124 *** (3.34)	3.308 ** (2.49)						
fdsr2	1.609 ** (2.49)	−3.472 *** (−2.92)	−1.863 (−1.47)						
fdse × ggti				−1.973 ** (−2.24)	4.480 ** (2.31)	2.507 (1.11)			
fdse				0.861 (1.32)	−1.714 (−1.50)	−0.853 (−0.70)			
fdse2				0.671 *** (2.72)	1.298 *** (2.64)	1.969 (4.14)			
fdsz × ggti							−0.340 (−0.87)	−0.904 (−1.35)	−1.245 * (−1.7)
fdsz							1.209 ** (2.43)	2.610 *** (2.70)	3.819 *** (3.78)
fdsz2							−0.907 *** (−2.62)	−1.744 *** (−2.68)	−2.650 *** (−4.01)
pgdp	−0.012 (−1.50)	0.017 (1.17)	0.005 (0.37)	−0.005 (−0.65)	0.005 (0.35)	0.000 (−0.01)	−0.011 (−1.41)	0.006 (0.44)	−0.005 (−0.32)
ur	−0.219 (−1.44)	−0.499 ** (−2.4)	−0.718 *** (−2.67)	−0.227 (−1.50)	−0.479 ** (−2.25)	−0.707 ** (−2.58)	−0.189 (−1.18)	−0.436 * (−2.00)	−0.625 ** (−2.24)
es	0.994 *** (8.66)	−0.191 (−0.87)	0.803 *** (3.80)	1.023 *** (9.04)	−0.265 (−1.24)	0.758 *** (3.85)	1.049 *** (8.84)	−0.048 (−0.22)	1.001 *** (4.98)
ind	0.387 ** (2.18)	−1.049 *** (−3.17)	−0.662 * (−1.85)	0.288 (1.62)	−1.130 *** (−3.18)	−0.842 ** (−2.15)	0.477 *** (2.81)	−0.468 (−1.54)	0.009 (0.03)
ope	0.176 ** (2.52)	−0.311 *** (−3.00)	−0.134 (−1.20)	0.161 ** (2.29)	−0.240 ** (−2.35)	−0.079 (−0.72)	0.294 *** (4.09)	−0.101 (−0.89)	0.193 * (1.65)
tec	−3.422 * (−1.69)	−0.998 (−0.28)	−4.421 (−1.07)	−2.136 (−1.06)	−5.986 * (−1.72)	−8.122 ** (−1.97)	−1.073 (−0.53)	−3.759 (−1.04)	−4.832 (−1.13)
ti	0.466 *** (3.80)	0.337 (1.39)	0.803 *** (3.06)	0.458 *** (3.55)	0.182 (0.68)	0.640 ** (2.18)	0.536 *** (4.15)	0.505 * (1.92)	1.041 *** (3.64)

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

According to the spatial effect decomposition results in Table 13, the signs and significance of the total effect of green taxation vary under the three dimensions of fiscal decentralization. This suggests that the role of green taxation in influencing carbon emissions does not depend solely on the tax itself, but on the specific fiscal decentralization framework within which it is implemented. This highlights the importance of integrating green taxation with complementary policy instruments and focusing on policy synergy.

5. Discussion

Based on the theoretical framework, literature review, and empirical findings of this study, the acceptance or rejection of the proposed hypotheses is summarized in Table 14.

Overall, the results challenge the conventional Pigouvian assumption that green taxation uniformly reduces carbon emissions (H1a rejected). Instead, a significant "Green Paradox" effect is observed, whereby green taxation is associated with increased local carbon emissions. This finding supports the hypothesis proposed by Sinn (2008) and may be attributed to China's unique fiscal incentive structures: under performance evaluation systems that prioritize economic growth, local governments may treat green taxes primarily as a source of fiscal revenue rather than as instruments for environmental regulation. In some

cases, governments may even offset the burden of higher taxes by relaxing environmental enforcement.

Table 14. Summary of hypothesis testing.

Hypothesis ID	Content	Supported	Key Evidence
H1a	Green taxation reduces localized carbon emissions.	Rejected	Tables 7 and 9
H1b	Green taxation increases localized carbon emissions.	Supported	
H2a	Fiscal expenditure decentralization has an inverted U-shaped effect on local emissions and a U-shaped effect on neighbors.	Partially Supported	Tables 7, 9 and 10
H2b	Fiscal revenue decentralization has an inverted U-shaped effect on local emissions and a U-shaped effect on neighbors.	Partially Supported	
H2c	Local financial autonomy has an inverted U-shaped effect on local emissions and a U-shaped effect on neighbors.	Partially Supported	
H3a	A higher degree of fiscal expenditure decentralization strengthens the carbon emission reduction effect of green taxation.	Partially Supported (Locally)	Tables 12 and 13
H3b	A higher degree of fiscal revenue decentralization strengthens the carbon emission reduction effect of green taxation.	Rejected	
H3c	A greater degree of local financial autonomy strengthens the carbon emission reduction effect of green taxation.	Supported	

The three dimensions of fiscal decentralization—revenue, expenditure, and autonomy—exhibit heterogeneous and nonlinear relationships with carbon emissions, reflecting the complexity of fiscal arrangements within China's decentralized governance structure (as also discussed by S. Chen & Gao, 2012). Specifically, the inverted U-shaped relationship associated with revenue decentralization suggests that, up to a certain threshold, economic growth competition remains the dominant driver of local government behavior.

Moreover, the significant negative spatial spillover effect (as indicated by the negative Wx term) supports the "pollution haven" hypothesis. This implies that stringent environmental policies in one region may displace carbon-intensive activities to neighboring areas with less stringent regulations, highlighting the necessity of regional coordination in environmental governance.

Most critically, the moderating effect of fiscal decentralization on green taxation (H3a–H3c) is confirmed, although its impact varies significantly across dimensions: revenue decentralization weakens the effectiveness of green taxes, fiscal autonomy enhances it, and expenditure decentralization yields mixed results. These findings underscore the importance of adopting a nuanced, multi-dimensional policy approach that integrates environmental and fiscal instruments effectively.

6. Conclusions and Implications

6.1. Conclusions

This paper investigates how green taxation influences carbon emissions within China's multidimensional fiscal decentralization system. Using the spatial Durbin model and provincial-level data from 2007 to 2022, the research reveals that green taxation alone is insufficient to reduce local carbon emissions and instead leads to increased emissions in neighboring provinces—evidence consistent with the "pollution haven" effect. Fiscal

decentralization initially stimulates both economic growth and emissions due to GDP-oriented incentives; however, this effect diminishes as regional economies develop further. The three dimensions of decentralization—revenue, expenditure, and autonomy—each demonstrate nonlinear (U-shaped or inverted U-shaped) relationships with both local and spillover emissions. Notably, revenue decentralization exacerbates the negative spatial spillovers associated with green taxation. This study contributes to the literature by incorporating all three dimensions of fiscal decentralization (rather than focusing on a single dimension), introducing interaction terms between decentralization and green taxation, and decomposing spatial effects to provide more precise insights into policy effectiveness.

6.2. Policy Implications

Based on our findings, we propose the following targeted policy recommendations:

Reform green taxation design and implementation: (1) Expand the coverage of resource taxes to include carbon-sink resources (e.g., forests and grasslands) and increase tax rates on fossil fuels. (2) Introduce explicit carbon emission components into the environmental protection tax. (3) Optimize vehicle and vessel taxes by incorporating carbon-based criteria, replacing traditional metrics such as weight or displacement. (4) Broaden the tax base of urban maintenance and construction taxes to include environmental and resource taxes, thereby enhancing funding for low-carbon infrastructure.

Differentiate fiscal decentralization strategies, implement place-based decentralization policies: Lwer-income regions should receive greater ecological compensation and fiscal transfers to prevent engaging in "race-to-the-bottom" competition. In contrast, high-income regions should be granted increased fiscal autonomy, conditional upon meeting stringent carbon reduction targets included in official performance evaluations.

Strengthen coordination between governments: (1) Establish cross-regional environmental cooperation mechanisms, harmonize regulatory standards, and promote the development of a unified carbon market. (2) Clarify the fiscal rights and responsibilities of both central and local governments concerning carbon emission reduction.

Most importantly, policy coordination between fiscal decentralization and green taxation should be enhanced to ensure their synergistic effects in reducing carbon emissions.

6.3. Limitations and Future Research

Although this paper examines the impact of green taxes on carbon emissions from the perspective of three fiscal decentralization evaluation indices, it focuses only on medium-caliber green taxes. To propose a green tax policy with practical significance, it is necessary to discuss the interaction between all green-oriented tax policies and fiscal decentralization. While the fiscal decentralization evaluation indices in this study are multi-dimensional, they primarily reflect the decentralization of "financial power." Other dimensions of decentralization under Chinese-style fiscal decentralization, such as management decentralization, environmental decentralization, local government borrowing levels, tax revenue shares, and administrative decentralization, should also be considered.

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