Research on the Effect of Green Fiscal and Tax Policies on Carbon Emissions - Evidence from Provincial Panel Data Models of China

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Abstract. The issue of carbon emissions was a major problem faced by the whole world. In the process of moving along the path of low carbonization in various fields, fiscal and taxation policy was an important tool for the government to guide and support it. This paper used provincial panel data (excluding Tibet) from 2003 to 2020 to test the effects of variables such as the share of green fiscal expenditure and the share of green tax revenue on carbon emissions through fixed effects models, differential GMM models and systematic GMM models. The empirical tests found, green taxes could indeed curb total carbon emissions at this stage in China, but green finance was still on the left side of the environmental Kuznets inverted U-shaped curve, and it had no inhibitory effect on carbon emissions. The robustness test based on a narrowly defined share of green tax expenditures also confirmed this conclusion. Through further regional tests, it was found that the inhibiting effect of the green tax share on carbon emissions had a significant effect in the eastern, central, northeastern and western regions of China, but the degree of significant effect varied, the degree of influence from large to small was as follows: eastern region > northeast region > central region > western region.

Keywords: Carbon emissions · green fiscal and tax policies · regional differences

1 Introduction

Environmental pollution caused by carbon dioxide emissions is a global problem, and its solution requires the participation and efforts of every country. In recent years, "low-carbon development" has become an important direction for productivity change in all countries. 178 countries signed the Paris Agreement in 2016, actively cooperating to reduce carbon emissions in response to global climate change. In 2020, the world emitted about 31.98 billion tons of carbon dioxide, a reduction of 2.056 billion tons or 6.04% year-on-year compared to 2019, of which carbon dioxide generated by energy consumption decreased by 5.8% year-on-year. In 2020, after China's commitment to "carbon peak and carbon neutral"(hereafter referred to simply as the Two-Carbon Goal), the pace of low-carbon development accelerated, and the concept of low carbon was becoming more and more prominent in the entire socio-economic operation, based on

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economic efficiency and pollution prevention. In the process of advancing along the low-carbon path in various fields, fiscal and tax policy was an important means for the government to guide and support it. It could not only motivate and attract the whole society to participate in the low-carbon initiative by means of financial subsidies and tax concessions, but also push the high-carbon emitters to take the initiative to seek changes by means of increasing tax burden, so as to integrate the rich policy contents with the carbon reduction plans of various fields, helping each field to solve the difficulties in the process of low-carbon development and successfully complete their respective dual-carbon plans. Under such circumstances, it is of great practical significance and worthy of long-term attention to discuss the impact of China's current green tax policy and green fiscal policy on carbon emissions, what factors affect carbon dioxide emissions, and whether there are differences in carbon emissions impact mechanisms in different provinces.

There have been many studies on green tax policies and green fiscal policies and carbon emissions at home and abroad. Their research mainly focused on the following aspects: (1) Yang Q and Liu H (2012) [1] used the STIRPAT model, selected China's data from 1995 to 2009, decomposed carbon emission intensity and per capita carbon emission as dependent variables, and analyzed regional differences. The results found that energy intensity was an important factor causing differences in carbon emission levels; Li Y (2016) [2] used the LMDI method to spatially decompose the changes in carbon emissions in 30 provinces and regions in China from 2000 to 2012, which found that the continuous decline in energy intensity, especially industrial energy intensity, effectively curbed national carbon emissions; Other scholars used the logarithmic difference method, the Dividis exponential decomposition method and the Kaya constant equation to study the impact factors of carbon emissions and concluded that the carbon intensity energy used and economic growth played a significant role in increasing carbon emissions [3–5]. (2) Research on the impact of green taxes on carbon emissions: Wang J, et al. (2021) [6] used the CGE model to conclude that environmental protection taxes had a synergistic effect on carbon emission reduction, while also emphasizing that the mitigation of the greenhouse effect could not be achieved by relying on one tax alone; Guo C (2013) [7] empirically tested the relationship between tax incentives and energy saving and emission reduction and found that tax incentives were beneficial to energy saving and emission reduction, but the effect was not strong and may be related to the fact that tax incentives are not binding. Cheng Y (2021) [8], by analyzing the dynamic relationship between carbon tax revenues and energy shifts in Sweden over the period 1990–2019, pointed out that the impact of carbon tax revenues on energy shifts may become ineffective after a certain threshold was reached, and therefore further policy enrichment and adjustment were needed for Sweden to achieve carbon neutrality; Joyashree Roy, et al. (2013) [9], by studying the fiscal policies of countries such as the UK and Germany, they pointed out that fiscal subsidies and taxation policies were powerful tools used by countries to promote a shift towards a decarbonized energy system; Fan Q, et al. (2021) [10] simulated the effects of pollution reduction and economic growth under three scenarios: "no environmental regulation policy", "environmental tax policy" and "environmental tax policy combined with pollution control subsidy policy". It was found that tax policy could motivate enterprises to pay attention to the social cost of pollution discharge and thus encourage them to invest in pollution control. The combination of fiscal and tax policies could better achieve the effect of emission reduction and economic growth; Hadfield et al. (2019) [11] took Melbourne's decarbonization initiatives as the research object and pointed out that the government could use financial means to promote sustainable development by purchasing low-carbon products, providing funds for the early stage of clean energy, and funding low-carbon technology pilots; Camila Gramkow (2019) [12] also highlighted that green fiscal incentives could promote green technology development and foster independent R&D capacity. (3) Research on regional carbon emission differences: Wang S. (2013) [13] used panel data econometric analysis to analyze the factors influencing per capita carbon emissions across the country and the east-west and central regions. It was found that the share of industry in the industrial structure had a positive effect on carbon emissions nationally, and the factor had a significant positive effect on the eastern region, but not on the central and western regions; Xu G (2011) [14] analyzed the factors influencing carbon emissions in the eastern and western regions using econometric methods; Other scholars divided the country into three regions, such as low emission, medium emission and high emission, according to the average carbon dioxide emission of each province, and analyzed the regional differences of different regions and their influencing factors, which mainly included population size effect, economic development effect, energy intensity effect and energy structure effect, etc [15–20].

Based on the existing research, the author found the following shortcomings in the research on green fiscal and tax policies and carbon emissions: (1) Most of the research on green fiscal and tax policies was on tax policy, but rarely on fiscal policy. (2) The selection of variables was not quite accurate, for example, some literature used industrial carbon emissions instead of total carbon dioxide emissions. (3) In the existing studies on regional carbon emission differences, few of them involved green tax policies and green fiscal policies.

This paper used provincial panel data from 2002 to 2020, and examined data related to carbon emissions and green fiscal and taxation through fixed effects models, differential GMM models and systematic GMM models. This paper analyzed the effects of two tools, the proportion of green fiscal expenditure and the proportion of green tax revenue, on carbon emissions. And according to the regional test, it further analyzed the direction that China's fiscal and taxation policies to promote dual carbon goals should focus on in the process of improvement, so that it could promote carbon reduction to the greatest extent.

2 Theoretical Logic and Research Hypothesis

The collection of carbon tax is conducive to the realization of energy saving and emission reduction, this has been verified in some European developed countries that have implemented carbon tax policies [8, 9, 11]. At present, although there is no tax directly targeting carbon emission reduction in China, with the gradual improvement of the green taxation system, both the enrichment of tax incentives and the reform of tax types will play a carbon reduction effect. In recent years, the idea of ecological civilization has also been incorporated into the reform of the taxation system. The green effect of China's resource tax, consumption tax and other taxes was increasingly strengthened, and the cost of carbon emissions was increased through the adjustment of tax elements such as the increase of tax rates and the expansion of taxation scope, stimulating the transformation of social production methods towards low carbon with the pain of taxation. Therefore, this paper made the following first assumption.

Hypothesis H1: Green tax policies have a disincentive effect on carbon emissions.

Fiscal instruments are important levers for regulating economic development. In the process of curbing carbon emissions, China has adopted various fiscal instruments such as green procurement and fiscal subsidies to positively stimulate low-carbon development at both the production and consumption ends. Regarding the role of fiscal policy and the impact of carbon emissions, there was not still a unification of current domestic and international research. Zhao Z and Tan J (2020) pointed out that the effect of fiscal expenditure on carbon emissions was in line with the environmental Kuznets curve, and the different stages of research also made the effect of fiscal expenditure on carbon emissions different. In the long run, fiscal policy was conducive to raising consumers' and producers' attention to carbon emission reduction, which helped them to form preference for low-carbon products when consuming or inputting factors of production, thus reducing carbon emissions. Therefore, this paper proposed the hypothesis that fiscal policy had a disincentive effect on carbon emissions. But on the other hand, because the proportion of China's current fiscal expenditure in environmental protection, energy conservation and carbon reduction was still relatively low, and there was a certain time lag in the effect of fiscal expenditure on carbon emissions, the current fiscal expenditure may not yet reach the inverted U-shaped inflection point, and fiscal expenditure and carbon emissions were still in the same direction of change. Therefore, this paper proposed the following assumptions.

Hypothesis H2: Our current green fiscal policy is ineffective in curbing carbon emissions.

3 Variable Selection and Definition

3.1 Indicator Selection

(1) Explanatory variable: Carbon emissions

According to the IPCC Fourth Assessment Report 2007, the main source of greenhouse gas increase was fossil fuel combustion, so this paper was based on historical end-use energy consumption data for each province for the measurement of CO2 emissions. The calculation method was based on the IPCC Guidelines for National Greenhouse Gas Emissions Inventories, 2006 Edition[1]. This was shown in Eq. (1).

$$LnCO2_{it} = \sum E_{ijt}(\boldsymbol{i} = 30; \boldsymbol{j} = 1, 2, \ldots \ldots 9) \quad (1)$$

[1] IPCC. 2006 IPCC Guidelines for national greenhouse gas inventories[R]. Intergovernmental Panel on Climate Change, 2006.

$LnCO2_{it}$ was the total amount of carbon emissions in province i in year t. E_{ijt} was the consumption of the jth energy source in province i in year t. η_j was the carbon emission factor of the jth energy source. As the consumption of various energy sources was a physical statistic in the original statistics, it must be converted into a standard statistic when measuring carbon emissions. According to the China Energy Statistics Yearbook, final energy consumption was divided into nine categories, including raw coal, coke, crude oil, gasoline, paraffin, diesel, fuel oil, natural gas and electricity. The conversion coefficients and carbon emission coefficients of 9 types of energy were shown in Table 1. The measurement unit of the conversion factor was ton standard coal/10,000 m^3, electricity was ton standard coal/10,000 kwh, and the unit of other energy was kg standard coal/kg, and ton carbon/ton standard coal for the carbon emission factor. Let's take an example of the calculation of formula (1). In 2003, the physical consumption of coke in Beijing was 4.3825 million tons, then the carbon dioxide emissions generated by Beijing's consumption of coke in 2003 should be calculated like this. $LnCO2_{\text{Beijing},2003,\text{Coke}} = 438.25 * 0.97 * 2.86 = 12.1579\text{milliontons}$. And so on, you can calculate the carbon dioxide emissions generated by other energy sources in Beijing in 2003, and the sum of them is Beijing's carbon dioxide emissions in 2003.

(2) Explanatory variables

A. Percentage of green tax revenue; b. Percentage of green fiscal spending.

In this paper, the specific calculation of the percentage of green tax revenue and the percentage of green fiscal expenditure for each province was as follows.

Percentage of green tax revenue = (resource tax + sewage charges + vehicle and vessel tax + vehicle purchase tax + consumption tax + urban maintenance and construction tax + urban land use tax + cultivated land occupation tax) / (total tax revenue + sewage charges) * 100%

Percentage of green fiscal expenditure = (energy conservation and environmental protection expenditure + science and technology expenditure + agriculture, forestry and water expenditure)/fiscal expenditure*100%

(3) Control variables

A. Coal consumption share: Energy consumption was the key source of carbon dioxide, and coal was the first in China's energy consumption. Therefore, the relationship between

Table 1. Carbon dioxide emission factors by energy type

	Raw Coal	Coke	Crude Oil	Petrol	Paraffin	Diesel	Fuel oil	Natural gas	Electricity
Standard volume conversion factor	0.71	0.97	1.43	1.47	1.47	1.46	1.43	13.3	1.23
Carbon emission factor	1.90	2.86	0.59	3.02	2.93	3.02	3.17	2.16	2.21

energy consumption and carbon emissions was chosen to be observed for the share of coal in total energy consumption. b. Secondary sector as a share of GDP: The secondary sector had a higher level of carbon emissions. Therefore, the share of the secondary sector in GDP was chosen to represent the development of the secondary sector in China. c. Tertiary sector as a share of GDP: Part of the tertiary sector also involved carbon emissions. Therefore, the share of tertiary sector in GDP was chosen to represent the development of the tertiary sector in China. d. GDP per capita (in natural logarithm). e. Total population at the end of the year (taken as the natural logarithm): a larger population was likely to result in more frequent economic activity and relatively higher carbon emissions. This variable was accounted for using the total population at the end of the year for each province in China. f. Urbanization rate.

3.2 Data Sources

Due to the incompleteness of the data from Hong Kong, Macao, Taiwan and Tibet, this paper collated relevant data from 30 provinces (autonomous regions and municipalities directly under the Central Government) in China from 2003 to 2020 for examination. The data were obtained from the China Finance Yearbook, China Taxation Yearbook, China Environment Yearbook, China Population Statistics Yearbook, China Energy Statistics Yearbook and China Statistical Yearbook.

The descriptive statistics for each data were shown in Table 2.

Table 2. Descriptive statistics

Variables	Sample size	Average value	Standard deviation	Maximum value	Minimum value
Carbon dioxide emissions (LnCO2)	540	10.22	0.80	11.96	7.40
Share of green tax revenue (Tax)	540	0.15	0.05	0.36	0.02
Share of green fiscal spending (Fin)	540	0.38	0.12	0.74	0.07
Share of coal consumption	540	0.44	0.16	0.87	0.01
Share of secondary sector in GDP	540	45.21	8.54	61.5	15.8

(*continued*)

Table 2. (*continued*)

Variables	Sample size	Average value	Standard deviation	Maximum value	Minimum value
Share of tertiary sector as a GDP	540	43.63	9.59	83.9	28.6
Ln (GDP per capita)	540	10.37	0.75	12.01	8.19
Ln (Total population)	540	8.18	0.75	9.44	6.28
Urbanization rate	540	0.54	0.14	0.90	0.26

4 Model Building and Empirical Analysis

4.1 Model Setting

Based on the above theoretical analysis, the following fixed-effects model was developed to examine the role of green tax policies and green fiscal policies in promoting high-quality development:

$$LnCO2_{it} = \beta_0 + \beta_1 Tax_{it} + \beta_2 Fin_{it} + \beta_3{}' control_{it} + \lambda_i + \eta_t + \varepsilon_{it} \tag{2}$$

where $LnCO2_{it}$ denoted the natural logarithm of the total carbon emissions of region $\boldsymbol{i}$ at year $\boldsymbol{t}$. Tax_{it} denoted the share of green tax revenue in region $\boldsymbol{i}$ at year $\boldsymbol{t}$. Fin_{it} denoted the share of green fiscal expenditures in region $\boldsymbol{i}$ at year $\boldsymbol{t}$. $control_{it}$ was the set of control variables, the share of coal consumption, the share of secondary industry in GDP, the share of tertiary industry in GDP, GDP per capita, total population and urbanization rate were used as control variables in this paper. λ_i denoted regional fixed effects, η_t denoted year fixed effects, and ε_{it} was random disturbance terms.

Since the actual level of carbon emissions in the current period would be greatly affected by the value of the previous period, that was, there was a problem of serial autocorrelation. At the same time, in addition to the control variables selected in this paper, there were inevitably other missing variables that may affect carbon emissions, which would cause the endogeneity problem of the model. For this reason, in addition to choosing fixed effects for the regressions, differential GMM models and systematic GMM models were introduced for estimation and comparison with fixed effects models. The models were built as follows.

$$LnCO2_{it} = \beta_0 + \beta_1 LnCO2_{i,t-1} + \beta_2 Tax_{it} + \beta_3 Fin_{it} + \beta_4{}' control_{it} + \lambda_i + \eta_t + \varepsilon_{it} \tag{3}$$

4.2 Model Estimation

In this paper, the model was first estimated by selecting fixed effects through model testing, while the explanatory variables and control variables may have endogeneity problems due to the lagged terms of the explanatory variables included in the panel data model constructed in this paper, so it was further estimated through differential GMM model and systematic GMM model. Table 3 showed the regression estimation results.

As can be seen from Table 3, the results of the fixed-effects model estimated showed that green taxes had a positive effect on curbing carbon emissions, and passed the 1% significance level test. Both the differential GMM model and the systematic GMM model passed the second-order differential autocorrelation test for the nuisance term, and the p-statistic value of the Sargan test was greater than 0.05, indicating that the

Table 3. Basic regression results

	Fixed effects model	Differential GMM model	System GMM model
$LnCO2_{i,t-1}$		−0.063** (0.027)	−0.040** (0.021)
Percentage of green tax revenue	−0.926*** (0.263)	−0.614*** (0.084)	−0.531*** (0.128)
Percentage of green finances spending	0.191 (0.128)	0.067* (0.037)	0.049* (0.027)
Share of coal consumption	1.155*** (0.144)	1.864*** (0.135)	1.888*** (0.152)
Share of secondary sector in GDP	0.010** (0.004)	0.018*** (0.005)	0.017*** (0.005)
Share of tertiary sector in GDP	0.008 (0.005)	0.003 (0.008)	0.003 (0.008)
GDP per capita	0.344*** (0.040)	0.453*** (0.060)	0.529*** (0.053)
Total population	0.599*** (0.140)	0.666*** (0.020)	0.649*** (0.025)
Urbanization rate	1.350*** (0.330)	2.295*** (0.359)	1.871*** (0.468)
_cons	−0.225 (1.115)	−1.821** (0.680)	−1.782** (0.620)
R^2	0.964		
AR(1)		0.000	0.000
AR(2)		0.677	0.622
Sargan		0.055	0.144

Note: ***, ** and * represent 1%, 5% and 10% significance respectively; brackets indicate the value of the standard error; the values of AR (1), AR (2) and Sargan are their respective p-values instrumental variables were valid, and the estimation results of both models also showed that green taxation policies could curb carbon emissions at the 1% significance level, which verified the research hypothesis H1. In the test of green fiscal policy, the difference GMM model and the system GMM model both passed the second-order difference of the disturbance term without autocorrelation test and the validity test of instrumental variables. The estimation results of the two also showed that at the 10% significance level, the coefficients of the three models were all positive, green fiscal policy could promote carbon emissions, which verified the research hypothesis H2, indicating that China's overall fiscal level was still in the environmental pool. The left side of the Kuznets inverted U-shaped curve has not yet played a positive role in suppressing carbon emissions, but instead had a promoting role.

In the tests of the control variables, the share of coal consumption increased carbon emissions, which passed the 1% significance test in the fixed effects, differential GMM models and systematic GMM models, indicating that achieving carbon reduction required a gradual reduction in reliance on coal. The coefficient of the share of the secondary sector in GDP was significantly positive in all three models, indicating that carbon emissions and the development of the secondary sector were congruent. The more dependent a region was on the development of the secondary sector, the greater its carbon emissions would be. Therefore, in the process of achieving China's dual carbon target, attention should be paid to the transformation and upgrading of the secondary industry, actively introducing low-carbon energy and green technologies, and promoting the decoupling of economic development and carbon emissions. Higher GDP per capita, total population and urbanization rate were also all positively and significantly associated with carbon emissions, passing the 1% significance test in fixed effects, differential GMM models and systematic GMM models. Economic development and environmental protection were mutually influential and constraining relationships, and in the context of the dual carbon target, low carbon and environmental protection were our goals while maintaining economic stability.

4.3 Robustness Tests

To ensure the robustness of the findings, the model was further estimated in this paper using a narrowly defined share of green tax revenue as the explanatory variable.

In addition to the broad green tax revenue share, there were also experts and scholars who studied the narrow green tax revenue share, defined as narrow green tax revenue share = emission fee/ (total tax + emission fee) *100%. This paper used this indicator to replace the broad green tax revenue share and conducted another robustness test on carbon tax to curb carbon emissions, and the estimated results were shown in Table 4.

Robustness tests with the share of narrowly defined green taxes as the core explanatory variable showed that green taxes still have a positive and positive effect on curbing carbon emissions, and that the estimates from both the differential GMM model and the systematic GMM model were significant at the 5% level. Coal consumption and the development of secondary and tertiary industries as well as GDP per capita, population size, and an increase in urbanization rate all increased carbon emissions. The model estimation results were similar to this and Table 3, indicating that the current model passed the robustness test.

Table 4. Robustness tests

	Fixed effects model	Differential GMM model	System GMM model
$LnCO2_{i,t-1}$		0.092*** (0.011)	0.100** (0.023)
Narrow green tax revenue share	−1.117** (0.558)	−0.646*** (0.248)	−0.504** (0.252)
Percentage of green finances spending	0.090 (0.094)	0.055* (0.034)	0.191 (0.270)
Share of coal consumption	1.058*** (0.153)	1.748*** (0.096)	1.752*** (0.176)
Share of secondary sector in GDP	0.014*** (0.004)	0.015*** (0.003)	0.012** (0.005)
Share of tertiary sector in GDP	0.011** (0.005)	0.011** (0.005)	0.005 (0.008)
GDP per capita	0.381*** (0.038)	0.859*** (0.109)	0.552*** (0.088)
Total population	0.296** (0.151)	0.667*** (0.020)	0.604*** (0.021)
Urbanization rate	0.919*** (0.336)	0.859* (0.504)	0.669* (0.375)
_cons	1.867 (1.205)	−1.821** (0.680)	−3.569*** (0.626)
R^2	0.961		
AR(1)		0.000	0.000
AR(2)		0.165	0.160
Sargan		0.055	0.302

Note: ***, ** and * represent 1%, 5% and 10% significance respectively; brackets indicate the value of the standard error; the values of AR (1), AR (2) and Sargan are their respective p-values

4.4 Regional Variation Test

To further investigate the regional differences in carbon emissions, the 30 provinces studied were divided into the eastern, central, western and northeastern regions according to the economic regional classification criteria. The results were as follows. The eastern region included: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The Central region included: Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. The Western region included: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The Northeast region included: Liaoning, Jilin and Heilongjiang. The models used were all systematic GMM models. The results of the regression analysis for each region were shown in Table 5.

Table 5. Results of the regression analysis for each region of the system GMM model

	East	Central	Western	Northeast
$LnCO2_{i,t-1}$	0.176* (0.096)	0.216* (0.115)	−0.056* (0.036)	−0.069** (0.025)
Percentage of green tax revenue	−1.950*** (0.750)	−1.905*** (0.732)	−1.195* (0.797)	−1.914*** (0.084)
Percentage of green finances spending	0.717 (1.089)	1.138** (0.427)	0.109* (0.067)	0.067* (0.045)
Share of coal consumption	2.140*** (0.683)	0.473* (0.251)	1.957*** (0.337)	1.864*** (0.135)
Share of secondary sector in GDP	0.023*** (0.008)	0.011** (0.005)	0.043*** (0.014)	0.018*** (0.005)
Share of tertiary sector in GDP	0.023** (0.011)	0.006** (0.003)	0.051** (0.019)	0.003 (0.008)
GDP per capita	0.167*** (0.064)	0.076*** (0.029)	0.722*** (0.194)	0.453*** (0.060)
Total population	0.927*** (0.110)	−0.147*** (0.056)	0.549*** (0.048)	−0.666*** (0.020)
Urbanization rate	−2.745** (1.257)	1.920* (1.533)	1.701 (1.458)	−2.295*** (0.359)
_cons	−1.135 (2.628)	7.883* (3.935)	1.151 (2.617)	−1.821** (0.680)
AR(1)	0.000	0.000	0.000	0.000
AR(2)	0.263	0.176	0.165	0.160
Sargan	0.345	0.455	0.055	0.302

Note: ***, ** and * represent 1%, 5% and 10% significance respectively; brackets indicate the value of the standard error; the values of AR (1), AR (2) and Sargan are their respective p-values

The regression results of the overall national situation (seen in Table 3) and the sub-regional situation (seen in Table 6) were analyzed. The analysis revealed that for the overall situation, the regression coefficients of the proportion of green fiscal expenditure, the proportion of coal consumption, the proportion of secondary and tertiary industries in GDP, GDP per capita, total population and urbanization ratio were all positive, which had a positive effect on total carbon emissions, while the regression coefficient of the proportion of green tax revenue was negative, which had a negative effect on total carbon emissions. The regression coefficients for the share of green fiscal expenditure, coal consumption, the share of secondary and tertiary industries in GDP, and GDP per capita were all positive, and the regression coefficient for the share of green tax revenue was negative, which was similar to the overall national situation.

There were differences between the total population and urbanization rate and the overall national situation. The regression coefficients of the total population in the central region and the northeastern region were negative and acted as a disincentive to carbon

Table 6. Summary of regression results by region

	East	Central	Western	Northeast
Percentage of green tax revenue	–	–	–	–
Percentage of green finances spending	+	+	+	+
Share of coal consumption	+	+	+	+
Level of industrialization	+	+	+	+
GDP per capita	+	+	+	+
Total population	+	–	+	–
Urbanization rate	–	+	+	–

Note: + means increasing carbon emissions, - means suppressing carbon emissions

emissions, while the regression coefficients of the urbanization rate in the eastern region and the northeastern region were negative and acted as a disincentive to carbon emissions. In terms of population size, the total population of the Northeast was at the bottom of the national scale, and the relatively small total population brought about less incremental carbon emissions. At the same time, the early industrialization had enabled the Northeast to complete the concentration of population earlier, realizing specialized division of labor and learning effects and improving efficiency, thus bringing about a more obvious reduction in carbon emissions. The central region had a large population size, a high degree of population density, and frequent exchanges of people, which could give better play to the agglomeration effect of the population and therefore play a very obvious role in reducing carbon emissions. According to previous research, the impact of urbanization on carbon emissions showed an inverted "U" shape relationship, with the eastern region and the northeastern region developing earlier in the industrialization process. In addition, the transportation system in the eastern region was widely and reasonably laid out, with better water, land and air access, and the comprehensive urbanization level has already passed the inflection point, thus exerting a suppressing effect of urbanization on carbon emissions.

The regression coefficients of the share of green taxes on carbon emissions in eastern, central, northeastern and western regions of China all showed a significant negative relationship, but the degree of influence was in the order of eastern, northeastern, central and western regions, which indicated that green tax policies in eastern, northeastern and central regions were conducive to curbing carbon emissions in the region, due to the higher level of governance of local governments in eastern and central regions, and the implementation of green tax policies and the setting of tax intensity were more agreeable. In contrast, the level of green development in the western region was still insufficient, and the green tax policy was less effective. In the future development, it is necessary to appropriately enhance the intensity of the green tax policy in the western region, so as to give full play to the ecological safeguard function of the western region. At the same time, an inter-regional ecological compensation mechanism should be constructed so as to achieve coordinated development between regions while greening development.

5 Conclusions

This paper used provincial panel data (excluding Tibet) from 2003 to 2020 as a sample, and used STATA as a modelling tool to establish fixed effects models, differential GMM models and systematic GMM models to study the research problem of the impact of green fiscal policies on carbon emissions. The results showed that: (1) green taxation at the current stage in China could indeed suppress total carbon emissions, but green fiscal increased carbon emissions, and the robustness test based on a narrowly defined share of green tax expenditures also confirmed this conclusion. (2) Variables such as share of coal consumption, share of secondary and tertiary industries in GDP, GDP per capita, total population size and urbanization rate were all positively correlated with carbon emissions. (3) Further regional tests revealed that the regression coefficients of the share of green taxes on carbon emissions showed a significant negative relationship in the eastern, central, northeastern and western regions of China, but the degree of significant effect varied, with the degree of influence ranging from the eastern, northeastern, central and western regions in descending order.

In order to effectively cope with the current pressure of emission reduction in China and to promote the realization of the "double carbon" target, some policy recommendations related to green finance and taxation can be deduced from the findings of this paper as follows: (1) Continue to improve and promote China's green taxation policy, such as the formulation of a special carbon tax, if the taxation policy to promote carbon emission reduction can be improved, which is of great significance to China's carbon emission reduction speed up and increase the amount of emission reduction. (2) Further explore effective green fiscal policies, promoting the green fiscal policy to step into the right side of the environmental Kuznets inverted U-shaped curve as soon as possible, it will play a positive role in promoting energy conservation and emission reduction in China. (3) On the premise of preserving energy supply, gradually reduce support for industries that mainly consume coal, reduce the proportion of coal consumption, and invest more resources in new energy construction and scientific and technological research and development. (4) The level of green development in the western region is not enough, and the role of green tax policies is less, so it is necessary to moderately increase the intensity of green tax policies in the western region in future development, and give full play to the ecological protection of the western region function.

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