Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Effects of Chinese-style fiscal decentralization on carbon emissions: is there a role for urban construction investment bonds?

Jianlong Wang, Yong Liu, Weilong Wang & Haitao Wu

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 3, 2158115
https://doi.org/10.1080/1331677X.2022.2158115

Effects of Chinese-style fiscal decentralization on carbon emissions: is there a role for urban construction investment bonds?

Jianlong Wang[a,b], Yong Liu[a,b], Weilong Wang[a] and Haitao Wu[c]

[a]School of Economics, Sichuan University, Chengdu, China; [b]Institute of Low Carbon Economy, School of Economics, Sichuan University, Chengdu, China; [c]School of Management and Economics, Beijing Institute of Technology, Beijing, China

ABSTRACT

Fiscal decentralization is the source of China's rapid economic growth, but inevitably leads to a surge in total carbon emissions. We verify whether the intermediary mechanism of real estate development and the urban construction investment bonds (UCIB) can share the fiscal pressure of local governments to provide empirical support to clarify and solve the realistic decentralization dilemma. This study conducted a spatial analysis of panel data from 266 Chinese prefecture-level cities from 2006 to 2019 and obtains the following findings. (1) Carbon emissions are spatially correlated, displaying the characteristics of 'one glory and one loss'. (2) Fiscal decentralization drives an increase in carbon emissions over the entire spatial region. (3) The decomposition results show that although fiscal decentralization aggravates local carbon emission growth, it benefits the carbon emission reduction of neighboring regions. (4) The eastern regions' fiscal decentralization does not significantly affect carbon emissions, whereas the central and western regions' fiscal decentralization causes an upsurge in total carbon emissions. (5) Fiscal decentralization has promoted the prosperous development of the real estate industry, which positively influences carbon emissions. (6) The UCIB has a negative moderating effect on fiscal decentralization and carbon emissions, implying that it plays a role in alleviating financial pressure on local governments. Accordingly, we propose relevant countermeasures: adjusting the degree of decentralization, controlling real estate development, and issuing UCIB.

ARTICLE HISTORY
Received 28 September 2022
Accepted 8 December 2022

KEYWORDS
Fiscal decentralization; carbon emission; spatial effect; real estate development; urban construction investment bonds

JEL CODES
Q51; Q58; R31

1. Introduction

Economic development is accompanied by energy consumption and resource depletion, which is a real predicament for all countries globally (Liu, Lei, et al., 2022; Ren

CONTACT Yong Liu yonghopeliu@sina.com

et al., 2022). In recent years, with the increasing global temperature and greenhouse effect, carbon emissions that cause the greenhouse effect have become the focus of international attention and pose a severe challenge to the sustainable development of the global economy. In 2007, the Intergovernmental Panel on Climate Change (IPCC) published its Fourth Assessment Report. It took 100 years for the Earth's surface to rise by an average of 0.74 °C, and global temperatures are projected to rise by 1.8 °C to 4 °C by 2100. In China, resource consumption and carbon emissions are increasing at an alarming rate. According to the BP World Energy Statistics Yearbook 2022, China has been the largest energy consumer market for the past 20 years. In 2021, China will account for 26.5 percent of global energy consumption. In addition, as a major component of energy consumption, fossil fuels emit large amounts of carbon dioxide during combustion. The resulting climate change has become a focus of attention worldwide. According to data released by the International Energy Agency (IEA)[1], 33.622 billion tons of carbon emissions were generated by fossil fuel combustion globally in 2019. China's fossil fuel combustion generates 9.876 billion tons of carbon emissions, accounting for 29.37% of global carbon emissions. Currently, China has an urgent and arduous task to achieve its 'double carbon' target.

Studies have confirmed a correlation between economic growth and carbon emissions (Qian & Roland, 1998; Qian & Weingast, 1996), and China's economic growth has benefited from a fiscal system with Chinese characteristics. After the tax system reform in 1994, the Chinese government devolved fiscal authority to local governments, giving them more autonomy to develop and form a unique Chinese-style fiscal decentralization system. Under the centralization of power, local governments have the right to control and choose. The extensive development model of first development and then governance became the mainstream choice for the local government's economic development. Combined with the 'lack of oil, less gas, more coal' energy structure, and underdeveloped technology, this determines the rigid nature of China's economic growth in terms of high energy demand, which leads to high carbon emissions. The regional distribution of carbon dioxide emissions is influenced by policy differences, economic and environmental differences, factor structure differences, and resource endowments among provinces in China. Therefore, exploring temporal trends in carbon dioxide emissions and their distribution across regions and fiscal decentralization to increase carbon emissions can contribute to the effective control of carbon emissions.

Fiscal decentralization not only increases the pressure on local governments but also results in a mismatch between financial and administrative power and an inadequate sub-provincial financial management system, which leads to the rising debt level of local governments. With high levels of debt, local governments have been selling land and vigorously developing real estate, resulting in a mismatch between land resources and pollution emissions. Local governments, looking to overcome financial trouble and reduce pollution emissions, have set up several financing platform companies across the region to boost local growth and cater to performance reviews by issuing UCIBs.

This study considers the effect of fiscal decentralization on carbon emissions within the framework of local government debt financing. An increase in the size of local government debt may have a complex effect on regional carbon emissions. On the one hand, the increase in the size of local government bond issuance to ensure the fiscal balance of local governments may further increase debt service pressure, which may encourage local governments to adopt incentives to attract a range of highly polluting enterprises to move in and develop. This incentive distortion is potentially significant in regions with a low fiscal balance. On the other hand, considering that the local government mainly invests in water construction, municipal infrastructure construction, river and lake management, industrial park infrastructure construction, and so on, especially in backward areas with poor fiscal balance, the UCIB's promoting effect on environmental pollution control is particularly remarkable. Therefore, we need to consider whether the UCIB release has eased fiscal pressure on local governments and the impact on carbon emissions, that is, whether the release of UCIB has a significant regulatory effect on fiscal decentralization and carbon emissions.

To solve these problems, the spatial effects of fiscal decentralization on carbon emissions are analyzed, and heterogeneity is discussed using the spatial Durbin model. We then break down the direct and indirect effects of fiscal decentralization on carbon emissions from the total effects and compare their differences. This study proves that real estate development is an intermediary variable of fiscal decentralization affecting carbon emissions. Finally, we analyze the moderating effect of issuing the UCIB on fiscal decentralization and carbon emissions.

The possible contributions of this study are as follows: By decomposing the total effect from the research perspective, we find that local fiscal decentralization affects local and neighborhood carbon emissions differently. From the perspective of the mechanism of fiscal decentralization affecting carbon emissions, we analyzed the new mechanism of real estate development. In terms of addressing the contribution of fiscal decentralization to carbon emissions, we found that issuing the UCIB is an effective way to reduce financial pressure on local governments and to change how local governments draw significant financial resources from property development to reduce carbon emissions.

The remainder of this paper is organized as follows. The second part summarizes the relevant literature on fiscal decentralization and carbon emissions. The third part analyzes the influence mechanism and proposes four hypotheses. The fourth part constructs the empirical analysis model and describes the data sources. The fifth section analyzes the empirical results, validates the four research hypotheses step by step, and carries out the heterogeneity analysis. The sixth section presents countermeasures based on reliable conclusions.

2. Literature review

2.1. Fiscal decentralization and carbon emissions

Early fiscal decentralization theories valued the efficiency of public goods provision, such as those of Tiebout (1956) and Oates and Schwab (1988), who argued that local governments have more informational advantages than the central government in providing public goods. The second generation of property decentralization theory emphasizes the relationship between decentralization and economic growth. While fitting the economic miracle of developing countries, especially China (Cao et al., 1999), scholars have begun to shift their efforts to fiscal decentralization, social justice, and environmental issues, as the adverse effects of economic development have grown.

It has been suggested that a linear relationship exists between fiscal decentralization and carbon emissions. Khan et al. (2021) show that fiscal decentralization reduces regional carbon emissions by increasing the level of human capital and improving the institutional environment. Hao et al. (2020) also revealed the same finding that fiscal decentralization is effective in reducing carbon emissions. Sun et al. (2022) found that fiscal decentralization effectively achieves environmental sustainability through renewable energy sources and green investments. Cheng et al. (2021) concluded that fiscal decentralization significantly improves the ecological quality of areas under government jurisdiction. Furthermore, scholars such as Ahmad et al. (2021), Su et al. (2021), and Zhang and Hussain (2021) have confirmed that fiscal decentralization has a dampening effect on environmental pollution and carbon emissions.

However, some studies have suggested that fiscal decentralization promotes the growth of carbon emissions. Lin and Zhou (2021) noted that fiscal decentralization leads to a vertical imbalance in local government finances, which inhibits innovation and industrial structure upgrading, thus impacting environmental performance and energy efficiency. Zhang et al. (2017) demonstrate that fiscal decentralization exacerbates carbon emissions by distorting local governments' behavior in introducing green policies. You et al. (2019) found that fiscal decentralization can lower the environmental regulation threshold, resulting in a decline in environmental quality. Van Der Kamp et al. (2017) argued that promotion incentives arising from fiscal decentralization encourage a 'race to the bottom' of local officials, exacerbating environmental pollution. In contrast, Cheng et al. (2020) concluded that increasing fiscal decentralization has different effects on carbon emissions, with total carbon emissions increasing with increasing per capita fiscal expenditure.

Another type of research focuses on the effects of government fiscal decentralization on environmental quality. For example, Wellisch (1995) argues that fiscal decentralization is positively related to regional environmental quality. Based on this study, Faguet (1999) found that local governments prefer to meet the needs of residents, thus ensuring that fiscal decentralization effectively reflects the environmental quality requirements of residents. He et al. (2021) empirically tests a significant positive relationship between the level of environmental pollution and local fiscal expenditure per capita in China. Meanwhile, other scholars are skeptical about the findings of this study. The results of Kunce and Shogren (2005), analyzed from the perspective of local government appraisal and market structure, suggest that local governments have some adverse effects of destructive competition in the process of preserving the economy and promoting growth, which in turn can cause different degrees of environmental pollution problems. Ogawa and Wildasi (2009) explored the relationship between the two from the perspectives of labor mobility and industry competition. The results of both studies confirm the conclusion that the higher the level of fiscal decentralization, the lower the region's environmental quality. López et al. (2011) concluded that increasing the share of social welfare and public goods spending in government spending would reduce pollutant emissions; however, increasing the total amount of government spending does not reduce pollutant emissions without changing the spending structure.

2.2. Other factors affecting carbon emissions

It has been revealed that carbon emissions are also influenced by factors such as technological innovation, foreign direct investment, openness to the outside world, industrial structure, population size, and urban greenery coverage. Many studies have explained that technological innovation is a crucial initiative for reducing carbon emissions (e.g. Erdogan, 2021; Liang et al., 2022; Ma et al., 2021; Wang, Mirza, et al., 2020). However, some scholars have argued that technological innovation leads to an increase in carbon emissions (e.g. Jiao et al., 2021; Liu, Zhang, et al., 2022; Yuan et al., 2022), which suggests that technological innovation causes an energy rebound effect from the technological progress (Herring & Roy, 2007; Liu, Liu, et al., 2018), contributing to the growth of carbon emissions. Regarding the impact of FDI on carbon emissions, most studies point to the ability of FDI to lead to 'pollution havens' and thus increase carbon emissions (Shahbaz, Balsalobre-Lorente, et al., 2019; Shahbaz, Gozgor, et al., 2019). Mahadevan and Sun (2020) discussed that FDI has a pollution abatement effect on the host country and can reduce carbon emissions in the incoming region. Furthermore, Guoyan et al. (2022) and Wang, Liao, et al. (2021) found that the effect of FDI on carbon emissions is nonlinear. Jijian et al. (2021) considered that there is a difference between trade exports and imports in the impact of foreign openings on carbon emissions, with imports more likely to promote the growth of carbon emissions in the region, whereas exports effectively reduce carbon emissions in the region. Li et al. (2022) pointed out that the development of international trade is a key factor in reducing carbon emissions. Wu et al. (2022) confirmed this view. However, Hao and Liu (2015) concluded that foreign openings had no significant effect on carbon emissions. Numerous studies have shown that industrial structure upgrading inhibits carbon emissions (e.g. Dong et al., 2020; Wu et al., 2021; Zhao et al., 2022). Rehman et al. (2021) inferred that an increase in population size positively affects carbon emissions in Pakistan. Zhang et al. (2014) and Anser et al. (2020) also demonstrated that population size increased carbon emissions. In contrast, Qi et al. (2020) stated that the scale effect due to population growth benefits carbon emission reduction. In addition, green coverage of cities is an external factor that affects carbon emissions (Liu, Zuo, et al., 2022; Zhang, Gao, et al., 2022).

3. Theoretical analysis and research hypothesis

3.1. The spatial impact of fiscal decentralization on carbon emissions and the mechanism

Fiscal decentralization provides local governments with greater autonomy. They have interest demands and are more willing to develop the economy than to focus on environmental quality improvement, to seek profit maximization under the existing incentive system. Local governments often ignore carbon emissions, even at the expense of the environment, in exchange for economic growth (Lin & Zhou, 2022;

Yang et al., 2022). Therefore, local governments' 'free-riding' behavior increases carbon emissions. Moreover, the behavior of local governments to attract liquid resources by using tax and environmental policies in their jurisdictions will only lead to increased carbon emissions, thus creating a distortion that emphasizes capital construction at the expense of environmental pollution (Wu et al., 2020).

The incentive for the promotion of officials is also inflated by the financial pressure of local governments, which will transfer the financial pressure to the primary land market to complete the performance assessment, achieve the promotion qualification, and get money using a 'bidding-auction-listing', forming land finance with Chinese characteristics (Liu, Fan, et al., 2018). Land finance has brought spring to China's real estate industry, which has entered a stage of rapid development. On the other hand, local governments use their control over land to transfer it to some enterprises and thus obtain land concessions used in real estate development and construction (Shu et al., 2018). It cannot be ignored that the upstream chain related to the real estate industry connects high energy consumption and high pollution high carbon emissions industries, such as steel, cement, metallurgy, chemical industry, and transportation industry, which will directly stimulate the growth of carbon emissions (Wang, Wu, et al., 2020).

In transition economies, local government revenues often fail to increase in proportion to fiscal expenditures, resulting in deficit and financing pressure on local governments, which will increase as decentralization reforms deepen (De Mello, 2000; Wildasin, 1996), This means that local governments in regions with high fiscal decentralization tend to face greater fiscal pressure, thereby lowering the pollution emission threshold of enterprises to attract investment (You et al., 2019).

From the perspective of rent-seeking by local governments, the prevalence of the real estate industry is often accompanied by the phenomenon that local governments attract foreign capital and high-energy-consuming industrial enterprises to move with low land prices (Lin & Ben, 2009), which provides a channel for the spatial transfer of carbon emissions. From the perspective of the spatial effect of carbon emissions, local governments will lower the carbon emission control constraint and use the meager land price to attract secondary industries with high mobility and high carbon emissions, which will bring some tax revenue to local governments but will undoubtedly increase local carbon emissions. In contrast, the highly polluting industries in the neighboring regions will relocate to the local production area with a low pollution reduction threshold, considering the cost of inter-regional environmental regulation and the need for the long-term development of enterprises, as well as the cycle and cost constraints of site transfer, which has a mitigating effect on carbon emissions in the neighboring regions (Chen et al., 2017). Based on the above analysis, we propose Hypotheses 1, 2, and 3.

Hypothesis 1: Fiscal decentralization positively contributes to the growth of carbon emissions.

Hypothesis 2: Fiscal decentralization promotes local carbon emissions, but contributes to neighboring regions' carbon emission reduction.

Hypothesis 3: The development of the real estate factory industry is a critical channel for fiscal decentralization to promote the growth of carbon emissions.

3.2. Moderating effect of UCIB on fiscal decentralization and carbon emissions

Under the current financial management system, the tax-based revenue system can no longer meet the local government's demand for funds to develop the local economy and needs to be financed by other means to meet the demand. The fluctuation of local government revenue is highly dependent on the change in land price, and the appreciation of land value can directly contribute to the increase in local government revenue, causing local governments to further rely on the revenue from land use rights to compensate for the shortage of funds and promote an increase in land prices. The increase in land prices enhances local governments' debt servicing capacity and reduces the fiscal gap to a certain extent. However, local governments spend their revenue on regional industrial development, which does not reduce the funding gap for urban infrastructure development.

Moreover, population inflow from regional industrial development requires supporting infrastructure investment, which widens the funding gap for infrastructure construction, and further increases the determination of local governments to develop the real estate sector in a short-sighted manner. This motivates local governments to tap into other ways to raise capital demand. As a result, local governments issue UCIB with credit guarantees (Zhang et al., 2018), thus providing financial assistance for 'Tiebout competition', which not only supports local infrastructure development and related production factor inflows (Ding et al., 2019) but also shares the pressure of fiscal expenditure, which allows local governments to adjust the structure of fiscal expenditure and allocate special funds for environmental management, thus reducing the promotion effect of fiscal decentralization on carbon emissions. In fact, UCIB uses are concentrated in water construction, river and lake management, and municipal infrastructure construction, meaning a considerable scale is used for regional environmental governance and construction, thus the UCIB has contributed to the improvement of regional environmental quality as an auxiliary instrument in the fiscal decentralization system. Based on the above analysis, this study proposes Hypothesis 4.

Hypothesis 4: UCIB negatively moderates the effect of fiscal decentralization on carbon emissions.

4. Model construction and variable selection

4.1. Model construction

4.1.1. Econometric model

Although some scholars have explored the impact of fiscal decentralization on carbon emissions using non-spatial measures (Khan et al., 2021; Tufail et al., 2021), they have ignored the spatial mobility of CO_2, which does not reflect the reality of the problem and thus results in biased estimates. Zhang et al. (2017) constructed a spatial model to extend the study of fiscal decentralization and carbon emissions, but they ignored the spatial spillover effects of fiscal decentralization. For this reason, we need to choose a spatial measurement method that can compensate for the shortcomings mentioned above and is relevant to this study. The spatial Durbin model incorporates the spatial association of random disturbance terms and examines the spatial influence of the dependent variable. Therefore, we use the spatial Durbin model to explore the impact of fiscal decentralization on carbon emissions and set the underlying model in the following form:

$$CO_{2it} = \alpha_0 + \rho \sum_{j=1}^{n} W_{ijt} CO_{2it} + \alpha_1 FD_{it} + \alpha_2 \sum_{i \neq j}^{N} W_{ijt} FD_{it} + \sum_{k=1}^{6} \delta_k X_{it} + \mu_i + \tau_t + \varepsilon_{it} \# \quad (1)$$

To test the mechanism of the effect of fiscal decentralization on carbon emissions, we followed the approach of Wang, Xu, et al. (2021) and constructed a model of fiscal decentralization on mechanism variables of the following form:

$$HOUSE_{it} = \alpha_0 + \rho \sum_{j=1}^{n} W_{ijt} HOUSE_{it} + \alpha_1 FD_{it} + \alpha_2 \sum_{i \neq j}^{N} W_{ijt} FD_{it} + \sum_{k=1}^{6} \delta_k X_{it} + \mu_i + \tau_t + \varepsilon_{it} \# \quad (2)$$

Furthermore, we explored solutions to fiscal decentralization to enhance carbon emissions. We argue that the UCIB could reduce financial pressure on local governments and reduce the positive effect of fiscal decentralization on carbon emission intensity. Therefore, we built a model to verify the moderating effect of UCIB on fiscal decentralization and carbon emissions as follows:

$$CO_{2it} = \alpha_0 + \rho \sum_{j=1}^{n} W_{ijt} CO_{2it} + \alpha_1 FD_{it} + \alpha_2 BONDS_{it} + \alpha_3 \overline{\overline{FD_{it}}} \times \overline{\overline{BONDS_{it}}} + \sum_{k=1}^{8} \delta_k X_{it} + \mu_i + \tau_t + \varepsilon_{it} \# \quad (3)$$

In Equations (1)–(3), $\overline{\overline{FD_{it}}} = \left(FD_{it} - \overline{FD_{it}}\right)$, $\overline{\overline{BONDS_{it}}} = \left(BONDS_{it} - \overline{BONDS_{it}}\right)$, where $\overline{FD_{it}}$, $\overline{BONDS_{it}}$ denotes the mean value of fiscal decentralization and UCIB in year t, respectively. In addition, i denotes city and t denotes year; CO_2 denotes carbon emissions; FD denotes fiscal decentralization; $HOUSE$ denotes house price, which is the mechanism variable; $BONDS$ denotes UCIB, which is the moderating variable; X denotes a series of control variables affecting carbon dioxide emissions, including technological innovation (*Innovation*), greenery level (*Greenery*), industrial structure (*Industry*), the level of foreign direct investment (*Fdi*), population size (*Population*), level of openness to the outside world (*Openness*), μ_i denotes urban fixed effects, τ_t denotes time fixed effects, and ε_{it} denotes random disturbance terms.

4.1.2. Spatial weight matrix setting

Considering the possible influence of different spatial weight matrices on the regression results, we adopt the row normalized form of the 0-1 matrix for regression, which is set in the form of if two prefecture-level cities are geographically adjacent $W_{ij} = 1,\ i \neq j$; otherwise, $W_{ij} = 0,\ i = j$.

4.1.3. Global moran's I setting

To verify the spatial correlation and agglomeration characteristics of carbon emissions, we construct the global Moran's I index, and the measurement formula is as follows:

$$Moran'sI = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(M_i - \overline{M}\right)\left(M_j - \overline{M}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}; (-1 \leq Moran'sI \ll 1)\# \quad (4)$$

In Equation (4), $S^2 = \frac{1}{n}\sum_{i=1}^{n}\left(M_i - \overline{M}\right)^2$, $\overline{M} = \frac{1}{n}\sum_{i=1}^{j} M_i$. The spatial correlation of carbon emissions is as follows: when Moran's $I > 0$, carbon emissions have a positive correlation among cities; when Moran's $I < 0$, carbon emissions have a negative correlation among cities; when Moran's $I = 0$, carbon emissions do not have a spatial correlation among cities.

4.2. Variables and data source

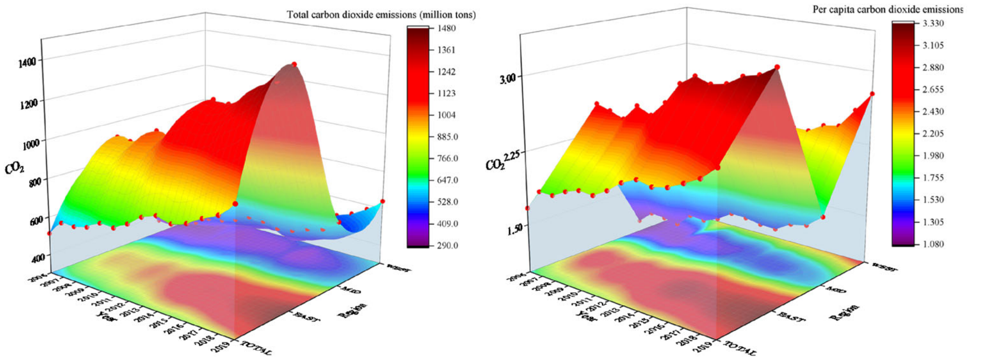
4.2.1. Dependent variable: Carbon emissions (CO_2)

Currently, there are two main methods of measuring carbon emissions. One is the sectoral accounting method and the other is the apparent emission accounting method. We referred to the method of Shan et al. (2018) and chose relatively readily available energy supply statistics to calculate the carbon emissions generated by fossil fuel combustion (raw coal, crude oil, and natural gas) and society-wide electricity consumption from the top-down. The specific approach is to multiply the apparent consumption of fuels by the corresponding carbon conversion factor and subtract the use and loss components of the apparent consumption of nonenergy fuels. Furthermore, we expressed the carbon emissions per capita by the ratio of the calculated total carbon emissions to the total population size of the prefecture-level city and performed a regression analysis.

We plotted the calculated total and per capita carbon emissions in a three-dimensional diagram to visualize China's carbon emissions trend from 2006 to 2019. It should be noted that, in Figure 1, the total carbon emissions and per capita carbon emissions are the average values of the emissions in the east, central, and west. As shown in Figure 1a, the total carbon emissions in the eastern region are significantly higher than those in the central and western regions, indicating that the eastern region has a developed economy and active production activities, but is also under great pressure to reduce carbon emissions. From Figure 1b, the per capita carbon emissions in the eastern region are still higher than the overall average value and those in the central and western regions. In addition, per capita carbon emissions in the western region are higher because of factors such as industrial shift and population size. From the vertical perspective of temporal development, both total and per capita carbon emissions showed an increasing trend in different regions.

4.2.2. Independent variable: Fiscal decentralization (FD)

Classic decentralized indicators include: 'expenditure indicators', 'revenue indicators', and 'fiscal autonomy indicators'. Academics have no rules for selecting indicators and



a Trend of total carbon emissions **b** Trends of per capita carbon emissions

Figure **1.** Spatial and temporal evolution of carbon emissions. (a) Trend of total carbon emissions; (b) trends of per capita carbon emissions.
Source: calculated by the authors and drawn using Origin software.

scholars can choose suitable indicators according to their research purposes. Since the founding of New China, the 'expenditure index' has been rising steadily. This trend does not reflect several important fiscal events in China, especially the decline in local fiscal freedom after the tax reform. Furthermore, 'revenue indicators' and 'fiscal autonomy indicators' can accurately depict the process of collecting and decentralizing data in each period, especially in tax sharing. At the same time, the income and expenditure indicators have limitations; they do not reflect regional differences but only reflect changes over time. Because such indicators have the same denominator at the same point in time, namely the financial information of the common province, the molecules and denominators of the 'fiscal autonomy' indicator formula, reflect both temporal and regional variations. Therefore, this study uses the financial autonomy index to describe the degree of fiscal decentralization using the ratio of local fiscal general budget expenditure to local fiscal general budget revenue.

4.2.3. Mechanism variable: real estate development (House)

We used the amount of completed real estate development investment to indicate the development of the local real estate sector and as an indicator variable for real estate development.

4.2.4. Moderating variable: UCIB

According to the definition and classification of the UCIB issued by each local financing platform in China by the China National Bond Registration and Settlement Company Limited, the UCIB strictly refers only to bonds whose issuing body is a municipal investment company. From the perspective of attributes, the local government financing platform is established as a company and capitalized by the local government, through which the local government can invest, finance, and operate its specific urban infrastructure and public welfare projects. Economic entities that can publicly issue corporate bonds, notes, financing bonds, non-public directed financing, and other bonds have independent legal personalities according to law. The government is regarded as the implicit guarantor of the bonds, so it is also called 'quasimunicipal bonds'. We manually collate the amount of UCIB issued by each provincial and regional financing platform each year and finally use the total amount of UCIB issued in the year and the cumulative amount of UCIB issued to represent the issuance scale of the municipal UCIB.

4.2.5. Control variables

The number of patent applications represents technological innovation. The greening coverage ratio characterizes the greening level. The value added by the secondary industry as a proportion of GDP is used to represent the industrial structure. Foreign direct investment is characterized by the amount of completed foreign direct investment. The total population of prefecture-level cities represents population size. The external openness level was measured as the sum of total imports and exports. In addition, we take the logarithms of the four absolute quantities of *Innovation*, *Fdi*, *Population*, and *Openness*.

4.2.6. Data sources

Based on data accessibility, we selected the balanced panel data of 266 prefecture-level cities from 2006 to 2019 (excluding the four municipalities of Beijing, Shanghai, Tianjin, and Chongqing) excluded cities with missing data, and made up the relevant missing data for a small sample of cities with missing data using the interpolation method. The original data for the above indicators were obtained from the China Urban Statistical Yearbook and the EPS database, and the original data for the UCIB were obtained from the Wind database. The descriptive statistics of the relevant data are shown in Table 1.

5. Empirical results and discussion

5.1. Applicability tests of the spatial model

We used LM, LR, WALD, and Hausman tests to demonstrate the applicability of the spatial Durbin model, and the test results are shown in Table 2. We found that the p-values of the LM, LR, WALD, and Hausman tests were all less than 0.01, indicating that the spatial Durbin model was valid. Therefore, the spatial Durbin model, with individual and time fixed, was selected to explore the correlation between the variables in this study.

Table 1. Descriptive statistics and definitions of variables.

Variables	Definition	Observation	Mean	Std. dev.	Min	Max
CO_2	Per capita carbon emissions	3,724	0.114	1.130	−3.315	3.547
FD	Fiscal decentralization	3,724	0.481	0.223	0.055	1.541
Innovation	Technology Innovation	3,724	6.703	1.723	1.792	12.023
Greenery	Greenery rate	3,724	0.388	0.0747	0.00590	0.953
Industry	Secondary Industry Structure	3,724	0.483	0.104	0.107	0.910
Fdi	Foreign Direct Investment	3,724	9.799	1.844	1.099	14.55
Popolation	Total population	3,724	5.886	0.642	3.400	7.313
Openness	Degree of openness to the outside world	3,724	13.71	2.006	7.223	19.62
House	Real estate industry development	3,724	13.82	1.312	9.268	17.34
UCIB	Urban construction investment bonds	3,724	36.37	99.02	0	1,326
Accumulated-UCIB	Accumulated urban construction investment bonds	3,724	141.6	420.8	0	6,105

Source: calculated by the authors using STATA software.

Table 2. Model applicability test.

Test Method	Statistical values	P-values
Moran's I	24.700	0.000
LM-error	594.530	0.000
LM-error (robust)	418.578	0.000
LM-lag	211.646	0.000
LM-lag (robust)	35.695	0.000
Hausman	210.31	0.000
LR-SAR	82.79	0.001
LR-SEM	71.86	0.000
WALD-SAR	84.16	0.001
WALD-SEM	72.24	0.007

Source: calculated by the authors using STATA software.

5.2. Spatial correlation analysis

Each prefecture-level city has a certain spatial dependence on the others due to its geographical location and different degrees of economic development. To clearly represent the spatial dependence, this study examines the spatial correlation of carbon emissions of 266 prefecture-level cities in China from 2006 to 2019. Table 3 shows the global Moran's I values of carbon dioxide emissions measured using the stata17 software. The Moran's I values of carbon dioxide emissions in China are all significantly positive at the 1% level, indicating a positive influence of carbon dioxide emissions among cities, reflecting that achieving carbon emission reduction requires the joint efforts of all regions.

5.3. Benchmark regression analysis

Before the baseline regression analysis, a scatter plot of carbon emissions and fiscal decentralization over the sample period was plotted and fitted, and the fit is shown in Figure 2. Evidently, these two variables are positively correlated.

Table 4 displays the regression results for fiscal decentralization and carbon emissions. Columns (1)–(3) present the regression results using ordinary least squares estimation (OLS), random effects (RE), and fixed effects (FE), respectively. Columns (4)–(6) show the results of regressions using the individual fixed (ind), time fixed (time), and double fixed (ind-time) spatial Durbin models, respectively. In columns (4)–(6), the ρ values are all significantly positive at the 1% level, indicating a strong

Table 3. The measurement results of global Moran's I of carbon emissions.

Year	Moran's I	Z-values	P-values
2006	0.3399	8.0640	0.0000
2007	0.3463	8.2140	0.0000
2008	0.3515	8.3358	0.0000
2009	0.3590	8.5172	0.0000
2010	0.3688	8.7409	0.0000
2011	0.3512	8.3283	0.0000
2012	0.3614	8.5695	0.0000
2013	0.3813	9.0340	0.0000
2014	0.3677	8.7199	0.0000
2015	0.4006	9.4917	0.0000
2016	0.4070	9.6420	0.0000
2017	0.3981	9.4308	0.0000
2018	0.3993	9.4606	0.0000
2019	0.3785	8.9718	0.0000

Source: calculated by the authors using STATA software.

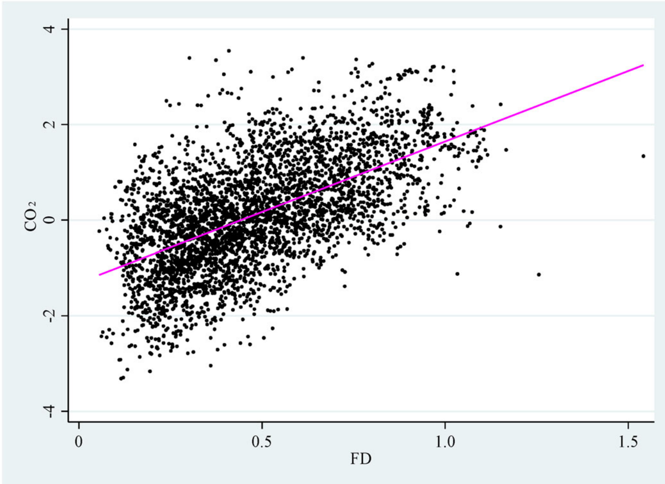


Figure 2. Scatter plot and fitted line of fiscal decentralization and carbon emissions.
Source: calculated by the authors and plotted using STATA software.

Table 4. Regression results of fiscal decentralization on carbon emissions.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OLS	RE	FE	ind	time	ind-time
FD	1.6290***	0.3270***	0.1228*	0.2390***	1.8030***	0.2413***
	(19.23)	(4.83)	(1.78)	(3.45)	(19.10)	(3.49)
Innovation	0.2230***	0.1042***	0.0618***	0.1281***	0.3357***	0.1029***
	(18.60)	(8.12)	(4.69)	(8.98)	(19.02)	(7.09)
Popolation	−1.0303***	−0.8122***	−0.6324***	−0.6014***	−1.0863***	−0.5967***
	(−47.32)	(−14.82)	(−6.91)	(−6.04)	(−42.84)	(−6.06)
Industry	0.1370	0.3113**	0.4516***	0.4756***	0.5132***	0.5931***
	(1.11)	(2.56)	(3.63)	(3.56)	(4.15)	(4.43)
Fdi	0.0065	0.0133**	0.0070	0.0131**	−0.0059	0.0112*
	(0.65)	(2.22)	(1.18)	(2.16)	(−0.61)	(1.85)
Openness	0.0663***	0.0647***	0.0312***	0.0680***	0.1037***	0.0546***
	(6.04)	(6.32)	(2.90)	(6.50)	(9.60)	(5.21)
Greenery	0.2917*	0.1941**	0.1744**	0.1775**	0.3944**	0.1223
	(1.69)	(2.15)	(1.96)	(2.09)	(2.56)	(1.45)
Constants	2.7475***	2.6290***	2.3291***			
	(17.24)	(8.07)	(4.33)			
$W \times FD$				−0.2432**	−1.1061***	−0.2160*
				(−2.27)	(−7.62)	(−1.92)
ρ				0.1707***	0.4336***	0.1256***
				(8.10)	(25.60)	(5.79)
σ^2				0.0751***	0.3791***	0.0734***
				(43.03)	(42.16)	(43.11)
N	3,724	3,724	3,724	3,724	3,724	3,724
R^2	0.6021		0.2520	0.5361	0.6247	0.3657

Note: t statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Source: calculated by the authors using STATA software.

spatial correlation with carbon emissions. In columns (1)–(6), the estimated coefficients of *FD* are all greater than 0, indicating that fiscal decentralization facilitates the growth of carbon emissions, and research hypothesis 1 is supported. Column (6) shows that the coefficient of *FD* is significant at the 1% level, implying that for every 1% increase in the degree of fiscal decentralization, carbon emissions will rise by 0.2413%. This finding is consistent with the results of Lin and Zhou (2021), Zhang et al. (2017), and You et al. (2019). However, the coefficient of the spatial lag term $W \times FD$ for fiscal decentralization is less than zero, suggesting that local fiscal decentralization has a carbon reduction effect on neighboring regions.

Since the central government implemented the 'tax sharing' reform, local governments have benefited from economic growth. Rapid local economic development increases local government tax revenues, improves government departments' welfare, and increases officials' opportunities for promotion. Therefore, local governments will naturally focus on economic development, while environmental protection policies, such as carbon emission reduction, will take a back seat. In addition, carbon emissions have a negative externality, whereas efforts to reduce emissions have a positive externality. As a result, many local governments are 'free-riding' on the issue of carbon emission reduction, leading to increased carbon emissions.

From the regression results of the control variables, technological innovation promotes carbon emissions, potentially because the technological progress of firms brought about by technological innovation expands the output of firms, but also expands the high demand for energy in each production sector, thus leading to the energy rebound effect of technological innovation. Population size significantly suppresses carbon emissions, potentially because population agglomeration usually generates a particular agglomeration force that increases production efficiency and reduces carbon emissions. Industrial structure positively affects carbon emissions, as the presence of energy-intensive and polluting industries in the secondary sector exacerbates carbon emissions owing to the massive demand for fossil energy and electricity. Foreign direct investment also drives the growth in carbon emissions. As a developing country, in China, FDI flows more into resource-consuming production activities, mainly when FDI flows into industries with high energy consumption, high pollution, and high carbon emissions, such as cement, steel, chemicals, and rubber, which require more energy resources and release large amounts of carbon dioxide. The development of foreign trade causes excessive consumption of natural resources, which in turn increases carbon emissions and causes regional environmental degradation (Mongelli et al., 2006). In addition, the effect of the green level on carbon emissions is insignificant.

5.4. Results of spatial effect decomposition

In this study, referring to LeSage and Pace (2009), the total effect is decomposed into local (direct) and neighboring (indirect) effects using a partial differential approach. The results of the decomposition effect are presented in Table 5. Column (1) shows

Table 5. Results of the decomposition of the total effect of fiscal decentralization on carbon emissions.

	Direct effect	Indirect effect
Variables	(1)	(2)
FD	0.2383***	−0.2108*
	(3.39)	(−1.76)
Control variables	YES	YES

Note: t statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Source: calculated by the authors using STATA software.

the local effects of fiscal decentralization. Column (2) shows the neighboring effect of fiscal decentralization, namely the spillover effect. From column (1), the coefficient of *FD* is greater than zero at the 1% level, indicating that for every 1% improvement in the degree of local fiscal decentralization, the carbon emissions in the region will rise by 0.2383% simultaneously, which directly contributes to the carbon emissions in the region. From column (2), the coefficient of *FD* is less than zero at the 10% level, which means that for every 1% increase in the degree of local fiscal decentralization, the carbon emissions of neighboring regions will shrink by 0.2108% in parallel. Local fiscal decentralization brings environmental benefits to neighboring regions. At this point, research hypothesis 2 of this study is verified.

Few studies have explored the spatial spillover effects of fiscal decentralization, namely, how fiscal decentralization in the region affects carbon emissions in neighboring regions. To this end, we offer the following explanation for the positive externalities of Chinese-style fiscal decentralization: local governments tend to relax regional carbon emission constraints based on the promotion incentive system for government officials that is unique to China (Jia, 2017). Local governments use low land prices and pollution emission thresholds as bait to attract heavy industrial enterprises. However, the high cost of relocating enterprises means that these incoming heavy polluters tend to originate from neighboring regions (Chen et al., 2017), leading to increased carbon emissions in the region and decreased carbon emissions in neighboring regions.

5.5. Robustness tests

1. Dynamic effect. We consider that carbon emissions in the current period may have been influenced by those in the previous period. Therefore, we include the lagged period of carbon emissions in Equation (1) and use the dynamic spatial Durbin model for regression. The results are shown in column (1) in Table 6.
2. Substitution of explanatory variables. We re-run the regression after including total carbon emissions as the explanatory variable; the outcome is shown in column (2) in Table 6.
3. Replacement matrix. We replace the spatial weight matrix with the economic geography matrix and use Equation (1) for regression estimation, the effect of which is shown in Column (3) in Table 6.
4. Endogeneity problem. Carbon emissions are widely a concern of the government, and the central government will formulate environmental regulation policies to regulate and guide the fiscal behavior of local governments, and improve the mismatch of fiscal revenues and expenditures. Therefore, the endogeneity problem may lead to bias in the estimation results of previous studies. For this reason, we used the systematic GMM method to re-verify the veracity and reliability of Hypothesis 1, and the results are shown in column (4) of Table 6. From column (4), we can see that the p-values of AR (2), the Sargan test, and the Hansen test are all greater than 0.1, which means that there is no second-order serial autocorrelation problem in the model, and the instrumental variables are selected effectively.

Table 6. Results of the robustness tests.

Variables	(1)	(2)	(3)	(4)
L.CO₂	0.9240***			0.9615***
	(80.36)			(66.44)
FD	0.0920**	0.2414***	0.2283***	0.0419*
	(1.97)	(3.49)	(3.28)	(1.87)
Innovation	0.0162	0.1027***	0.0918***	0.0067
	(1.63)	(7.08)	(6.35)	(1.15)
Popolation	−0.2521***	0.4031***	−0.6252***	−0.0316*
	(−3.78)	(4.09)	(−6.46)	(−1.95)
Industry	0.1398	0.5930***	0.7001***	−0.0583
	(1.50)	(4.42)	(5.34)	(−1.57)
Fdi	0.0066	0.0112*	0.0106*	−0.0027
	(1.62)	(1.85)	(1.75)	(−0.81)
Openness	0.0147**	0.0546***	0.0468***	−0.0032
	(2.04)	(5.21)	(4.48)	(−0.78)
Greenery	−0.0578	0.1222	0.1653*	0.7087*
	(−0.98)	(1.45)	(1.95)	(1.82)
Constants				−0.0161
				(−0.14)
ρ	0.0605***	0.1257***	0.2541**	
	(3.49)	(5.80)	(1.96)	
σ^2	0.0332***	0.0734***	0.0744***	
	(44.77)	(43.11)	(43.14)	
AR (1)				[0.000]
AR (2)				[0.985]
Sargan test				[0.961]
Hansen test				[0.168]
N	3458	3724	3724	3458
R^2	0.9566	0.1698	0.1752	

Note: t statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The p-values are in [].
Source: calculated by the authors using STATA software.

After conducting robustness tests using the above four methods, we find that fiscal decentralization significantly promotes carbon emissions, at least at the 10% level, proving that this study's empirical results are robust.

5.6. Regional heterogeneity

The step-by-step strategy of China's economic development has differentiated the fiscal funding needs among regions. Local governments face different fiscal pressures, making the fiscal revenue and expenditure structures vary widely across regions. This may create the heterogeneous impact of decentralization on carbon emissions. Therefore, dividing the sample into eastern, central, and western regions is imperative to examine the heterogeneity of the baseline regression results. Figure 3 depicts the significance of the coefficients of *FD* for different regions. The carbon growth effect of decentralization is consistent with the benchmark regression results in the central and western regions but has no significant effect on the eastern region. The reason for these results may be that because most of the eastern provinces are developed regions, the higher the degree of fiscal decentralization, the more powerful it is for the local economy. The more technologically advanced these regions, the better they are at reducing emissions. Furthermore, because most of the provinces in the central and western regions are backward regions, most of these provinces are still dominated by secondary industries that generate more pollution. The local technology lags

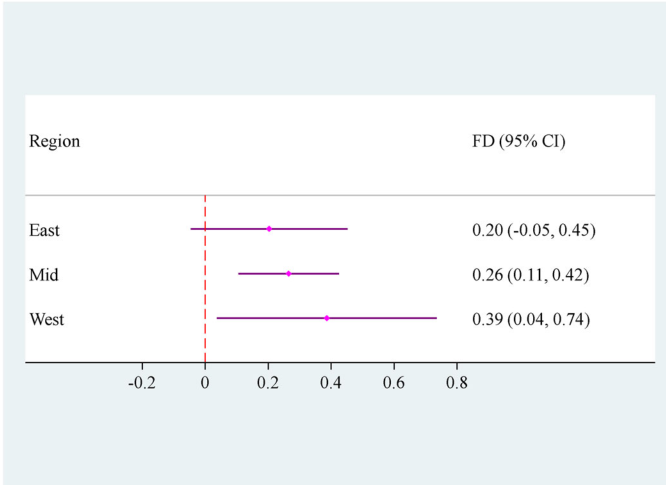


Figure 3. Regression results of regional heterogeneity.
Source: calculated by the authors and plotted using STATA software.

behind the developed regions (Zheng et al., 2022); they cannot carry out carbon emission reduction, and even fiscal decentralization aggravates local carbon emissions.

5.7. Mechanism Analysis

Based on the mechanism analysis in section 2, it is clear that real estate development may mediate the relationship between fiscal decentralization and carbon emissions. We conducted a regression analysis of Equation (2) and plotted the results in Figure 4. The estimated coefficient of *FD* was 0.23, which is within the 95% confidence interval. The confidence interval did not include a value of zero. This implies that the contribution made by fiscal decentralization to real estate development is statistically significant, and Hypothesis 3 is thus supported.

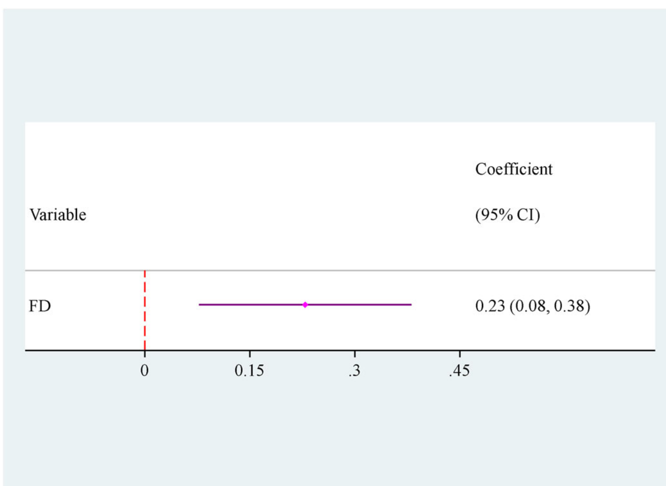


Figure 4. Regression results of fiscal decentralization on real estate development.
Source: calculated by the authors and plotted using STATA software.

Under the tax-sharing fiscal system, it is difficult for local governments to meet their fiscal expenditures by relying on fiscal revenues and transfers from higher-level governments. The tax-sharing system does not eliminate the system of off-budget funds. When the growth of regulated and formal local tax revenues could not compensate for the growth in expenditures, local governments at all levels increased their disposable financial resources by expanding extra-budgetary and extra-system revenues as much as possible in the face of fiscal pressure. With the rise of urbanization and the introduction of the land grant system across the country, the land-dependent real estate industry expanded and revenue from land sales began to become a new growth point for local government revenues. Hu and Qian (2017) also confirm that fiscal decentralization contributes to the boom in China's real estate industry by stimulating an increase in house prices. Wang, Wu, et al. (2020) found that the boom in the real estate sector led to the development of upstream industries, such as steel, cement, metallurgy, and building materials, which in turn significantly stimulated an increase in carbon emissions. In summary, developing the real estate sector is an important channel through which Chinese-style fiscal decentralization drives an increase in carbon emissions.

5.8. The moderating effect of UCIB

Can the issuance of UCIB alleviate the fiscal pressure of local policies and improve the fiscal expenditure structure, thereby changing the negative impact of decentralization on carbon emissions? To answer this question, we adopt a double-fixed spatial Durbin model to regress Equation (3). In this study, we create interaction terms between the total and cumulative issuances of the UCIB in the current year and fiscal decentralization, respectively. No control variables are added to the regression equations in columns (1) and (3) of Table 7, while all control variables are included in columns (2) and (4). Columns (1) and (2) show the results of the moderating variable of UCIB issuance in the current year, while columns (3) and (4) show the moderating effect of cumulative UCIB issuance on decentralization.

Overall, the coefficients of $FD \times UCIB$ and $FD \times Accumulated - UCIB$ are less than zero, at least at the 5% level, indicating that UCIB negatively moderates the

Table 7. Regression results of the moderating effect of UCIB on fiscal decentralization and carbon emissions.

Variables	(1)	(2)	(3)	(4)
FD	0.3990***	0.2943***	0.3952***	0.2951***
	(5.57)	(4.12)	(5.52)	(4.15)
UCIB	0.0008***	0.0007**		
	(2.92)	(2.41)		
FD×UCIB	−0.0011***	−0.0007**		
	(−3.17)	(−2.03)		
Accumulated-UCIB			0.0002***	0.0002**
			(3.05)	(2.57)
FD×Accumulated-UCIB			−0.0003***	−0.0002**
			(−3.26)	(−2.18)
Control variables	NO	YES	NO	YES
N	3724	3724	3724	3724
R^2	0.2396	0.3991	0.2408	0.3990

Note: t statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Source: calculated by the authors using STATA software.

effect of decentralization on carbon emissions. This implies that the issuance of municipal bonds reduces the financial pressure on local governments, making fiscal decentralization beneficial to carbon emission reduction. Therefore, Hypothesis 4 was supported. The increase in municipal investment bonds, mainly used for regional environmental management and construction, has a dampening effect on the 'incentive distortion' effect of fiscal decentralization. Zhang et al. (2018) pointed out that local governments provide financial assistance for 'promotion' by issuing the UCIB, which supports regional infrastructure construction. Ding et al. (2019) also argued that issuing UCIB could bring relevant production factors to local enterprises. Accordingly, UCIB shares the pressure of fiscal expenditure with local governments, which allows them to adjust the structure of fiscal expenditure and allocate special funds for environmental management, thus reducing the promotion effect of fiscal decentralization on carbon emissions.

6. Conclusions and recommendations

We collated and measured the debt size of the UCIB to local financing platforms. The direct, spillover, indirect, and moderating effects on fiscal decentralization and carbon emissions were examined in the framework of government debt, revealing the following exciting findings. First, fiscal decentralization is beneficial to the growth of carbon emissions. However, after decomposing the effects, we find that local fiscal decentralization affects local and neighboring locations' carbon emissions differently. Second, there is regional heterogeneity in terms of the impact of fiscal decentralization on carbon emissions, and the magnitude and significance of this effect vary across regions. Third, fiscal decentralization can affect carbon emissions by influencing the development of the real estate sector. Finally, UCIB is an important moderating variable for the impact of fiscal decentralization on carbon emissions. Therefore, this study proposes the following countermeasures.

First, given that fiscal decentralization can directly drive the growth of carbon emissions in the region, it shows that the central government must promote the reform of local fiscal decentralization. The central government should change the GDP-driven promotion incentive system and improve the fiscal relationship between the central and local governments. They should appropriately introduce environment-related assessment items, such as environmental governance and environmental responsibility, to guide local finances toward environmental protection.

Second, from the regression results of regional heterogeneity, the central government can also scientifically allocate financial and administrative powers between regions according to the economic development levels of different regions so that the financial and administrative powers of both economically developed regions and relatively backward regions can be matched. At the same time, consideration should be given to increasing the scale and proportion of central transfer payments to enhance the capacity and efficiency of local governments in providing public goods.

Third, carbon emissions are spatially correlated and positive externalities characterize fiscal decentralization. Strengthening the joint prevention and control of carbon emissions management among regions is still an effective policy for coordinating environmental governance. With the development of China's urban areas, local governments should incorporate joint governance into the scope of regional cooperation and development based on the joint promotion of economic growth to avoid 'free-riding' behaviors that harm the interests of both sides.

Fourth, real estate development is an important channel for fiscal decentralization to increase carbon emissions. Therefore, local governments must establish a long-term mechanism for the healthy development of real estate and form a scientific, industrial hierarchy, and operation system. Real estate cannot be used as a 'pillar industry' or a short-term means to stimulate rapid economic growth. The government needs to reasonably plan for the scale of real estate investment and guide enterprises to rationalize their investment structure. Resource and environmental indicators, and other related elements should be included in the assessment of real estate enterprises to promote the decoupling of real estate growth and carbon emission constraints.

Finally, the issuance of UCIB eased financial pressure on local governments and promoted carbon emission reduction. Therefore, local governments should strengthen the management of urban investment debt, allocate the issuance scale of UCIB reasonably, and use UCIB reasonably to solve the fiscal crisis. The issuance of UCIB must consider the region's demand, carrying capacity, and repayment ability. Simultaneously, the use of debt should be economical and service-oriented, thus improving the efficiency of debt issuance.

Although we analyzed the relationship between fiscal decentralization and carbon emissions from the perspective of UCIB, there are still the following shortcomings: On the one hand, fiscal decentralization includes three types of fiscal expenditure, fiscal revenue, and fiscal autonomy, while fiscal autonomy is used to measure fiscal decentralization. Future research could explore the differential impact of fiscal decentralization on carbon emissions from fiscal expenditure and revenue perspectives. However, we manually collected and collated the scale of debt issued by local municipal investment companies and may have missed a small amount of data. Future research can be based on better operation software, such as the data cleaning function of Python software, to obtain more accurate and reliable UCIB data. In addition, we only introduced UCIB as a moderating variable in the model and did not analyze the direct effect of UCIB on carbon emissions. Future studies should focus on analyzing the relationship between UCIB and carbon emissions to fill the gap in the present study.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Data from the International Energy Agency (http://www.iea.org/statistics/)

Funding

This work was supported by the National Social Science Fund of China (Grant No. 19XJY007).

ORCID

Jianlong Wang http://orcid.org/0000-0002-4360-6585
Yong Liu http://orcid.org/0000-0001-6741-4863
Weilong Wang http://orcid.org/0000-0001-8608-1267
Haitao Wu http://orcid.org/0000-0002-5592-7212

References

Ahmad, F., Xu, H., Draz, M. U., Ozturk, I., Chandio, A. A., Wang, Y., & Zhang, D. (2021). The case of China's fiscal decentralization and eco-efficiency: Is it worthwhile or just a bootless errand? *Sustainable Production and Consumption*, *26*, 89–100. https://doi.org/10.1016/j.spc.2020.09.014

Anser, M. K., Alharthi, M., Aziz, B., & Wasim, S. (2020). Impact of urbanization, economic growth, and population size on residential carbon emissions in the SAARC countries. *Clean Technologies and Environmental Policy*, *22*(4), 923–936. https://doi.org/10.1007/s10098-020-01833-y

Cao, Y., Qian, Y., & Weingast, B. R. (1999). From federalism, Chinese style to privatization, Chinese style. *The Economics of Transition*, *7*(1), 103–131. https://doi.org/10.1111/1468-0351.00006

Chen, L., Xu, L., & Yang, Z. (2017). Accounting carbon emission changes under regional industrial transfer in an urban agglomeration in China's Pearl River Delta. *Journal of Cleaner Production*, *167*, 110–119. https://doi.org/10.1016/j.jclepro.2017.08.041

Cheng, Y., Awan, U., Ahmad, S., & Tan, Z. (2021). How do technological innovation and fiscal decentralization affect the environment? A story of the fourth industrial revolution and sustainable growth. *Technological Forecasting and Social Change*, *162*, 120398. https://doi.org/10.1016/j.techfore.2020.120398

Cheng, S., Fan, W., Chen, J., Meng, F., Liu, G., Song, M., & Yang, Z. (2020). The impact of fiscal decentralization on CO2 emissions in China. *Energy*, *192*, 116685. https://doi.org/10.1016/j.energy.2019.116685

De Mello, L. R. Jr, (2000). Fiscal decentralization and intergovernmental fiscal relations: A cross-country analysis. *World Development*, *28*(2), 365–380. https://doi.org/10.1016/S0305-750X(99)00123-0

Ding, Y., McQuoid, A., & Karayalcin, C. (2019). Fiscal decentralization, fiscal reform, and economic growth in china. *China Economic Review*, *53*, 152–167. https://doi.org/10.1016/j.chieco.2018.08.005

Dong, B., Ma, X., Zhang, Z., Zhang, H., Chen, R., Song, Y., Shen, M., & Xiang, R. (2020). Carbon emissions, the industrial structure and economic growth: Evidence from heterogeneous industries in China. *Environmental Pollution (Barking, Essex : 1987)*, *262*, 114322. https://doi.org/10.1016/j.envpol.2020.114322

Erdogan, S. (2021). Dynamic nexus between technological innovation and building sector carbon emissions in the BRICS countries. *Journal of Environmental Management*, *293*, 112780. https://doi.org/10.1016/j.jenvman.2021.112780

Guoyan, S., Khaskheli, A., Raza, S. A., & Shah, N. (2022). Analyzing the association between the foreign direct investment and carbon emissions in MENA countries: A pathway to sustainable development. *Environment, Development and Sustainability*, *24*(3), 4226–4243. https://doi.org/10.1007/s10668-021-01613-8

Faguet, J. P. (1999). Does decentralization increase responsiveness to local needs? Evidence from Bolivia. *Evidence from Bolivia*, (November 30, 1999).

Hao, Y., Chen, Y. F., Liao, H., & Wei, Y. M. (2020). China's fiscal decentralization and environmental quality: Theory and an empirical study. *Environment and Development Economics*, *25*(2), 159–181. https://doi.org/10.1017/S1355770X19000263

Hao, Y., & Liu, Y. M. (2015). Has the development of FDI and foreign trade contributed to China's CO2 emissions? An empirical study with provincial panel data. *Natural Hazards*, *76*(2), 1079–1091. https://doi.org/10.1007/s11069-014-1534-4

He, A., Xue, Q., Zhao, R., & Wang, D. (2021). Renewable energy technological innovation, market forces, and carbon emission efficiency. *The Science of the Total Environment*, *796*, 148908. https://doi.org/10.1016/j.scitotenv.2021.148908

Herring, H., & Roy, R. (2007). Technological innovation, energy efficient design and the rebound effect. *Technovation*, *27*(4), 194–203. https://doi.org/10.1016/j.technovation.2006.11.004[Mismatch] https://doi.org/10.1016/S0305-750X(99)00123-0

Hu, F. Z., & Qian, J. (2017). Land-based finance, fiscal autonomy and land supply for affordable housing in urban China: A prefecture-level analysis. *Land Use Policy*, *69*, 454–460. https://doi.org/10.1016/j.landusepol.2017.09.050

Jia, R. (2017). Pollution for promotion. *21st Century China Center Research Paper*, (2017-05). https://doi.org/10.2139/ssrn.3029046

Jiao, Z., Sharma, R., Kautish, P., & Hussain, H. I. (2021). Unveiling the asymmetric impact of exports, oil prices, technological innovations, and income inequality on carbon emissions in India. *Resources Policy*, *74*, 102408. https://doi.org/10.1016/j.resourpol.2021.102408

Jijian, Z., Twum, A. K., Agyemang, A. O., Edziah, B. K., & Ayamba, E. C. (2021). Empirical study on the impact of international trade and foreign direct investment on carbon emission for belt and road countries. *Energy Reports*, *7*, 7591–7600. https://doi.org/10.1016/j.egyr.2021.09.122

Khan, Z., Ali, S., Dong, K., & Li, R. Y. M. (2021). How does fiscal decentralization affect CO2 emissions? The roles of institutions and human capital. *Energy Economics*, *94*, 105060. https://doi.org/10.1016/j.eneco.2020.105060

Kunce, M., & Shogren, J. F. (2005). On interjurisdictional competition and environmental federalism. *Journal of Environmental Economics and Management*, *50*(1), 212–224. https://doi.org/10.1016/j.jeem.2004.11.004

LeSage, J., & Pace, R. K. (2009). *Introduction to spatial econometrics*. Chapman and Hall/CRC. https://doi.org/10.1201/9781420064254

Li, Y., Alharthi, M., Ahmad, I., Hanif, I., & Hassan, M. U. (2022). Nexus between renewable energy, natural resources and carbon emissions under the shadow of transboundary trade relationship from South East Asian economies. *Energy Strategy Reviews*, *41*, 100855. https://doi.org/10.1016/j.esr.2022.100855

Liang, T., Zhang, Y. J., & Qiang, W. (2022). Does technological innovation benefit energy firms' environmental performance? The moderating effect of government subsidies and media coverage. *Technological Forecasting and Social Change*, *180*, 121728. https://doi.org/10.1016/j.techfore.2022.121728

Lin, S. W., & Ben, T. M. (2009). Impact of government and industrial agglomeration on industrial land prices: A Taiwanese case study. *Habitat International*, *33*(4), 412–418. https://doi.org/10.1016/j.habitatint.2009.01.001

Lin, B., & Zhou, Y. (2021). Does fiscal decentralization improve energy and environmental performance? New perspective on vertical fiscal imbalance. *Applied Energy*, *302*, 117495. https://doi.org/10.1016/j.apenergy.2021.117495

Lin, B., & Zhou, Y. (2022). Understanding the institutional logic of urban environmental pollution in China: Evidence from fiscal autonomy. *Process Safety and Environmental Protection*, *164*, 57–66. https://doi.org/10.1016/j.psep.2022.06.005

Liu, Y., Fan, P., Yue, W., & Song, Y. (2018). Impacts of land finance on urban sprawl in China: The case of Chongqing. *Land Use Policy*, *72*, 420–432. https://doi.org/10.1016/j.landusepol.2018.01.004

Liu, H., Lei, H., & Zhou, Y. (2022). How does green trade affect the environment? Evidence from China. *Journal of Economic Analysis*, *1*(1), 1–27.

Liu, W., Liu, Y., & Lin, B. (2018). Empirical analysis on energy rebound effect from the perspective of technological progress—A case study of China's transport sector. *Journal of Cleaner Production*, *205*, 1082–1093. https://doi.org/10.1016/j.jclepro.2018.09.083

Liu, X., Zhang, S., & Bae, J. (2022). Nonlinear analysis of technological innovation and electricity generation on carbon dioxide emissions in China. *Journal of Cleaner Production*, *343*, 131021. https://doi.org/10.1016/j.jclepro.2022.131021

Liu, W., Zuo, B., Qu, C., Ge, L., & Shen, Q. (2022). A reasonable distribution of natural landscape: Utilizing green space and water bodies to reduce residential building carbon emissions. *Energy and Buildings*, *267*, 112150. https://doi.org/10.1016/j.enbuild.2022.112150

López, R., Galinato, G. I., & Islam, A. (2011). Fiscal spending and the environment: theory and empirics. *Journal of Environmental Economics and Management*, *62*(2), 180–198. https://doi.org/10.1016/j.jeem.2011.03.001

Ma, Q., Murshed, M., & Khan, Z. (2021). The nexuses between energy investments, technological innovations, emission taxes, and carbon emissions in China. *Energy Policy*, *155*, 112345. https://doi.org/10.1016/j.enpol.2021.112345

Mahadevan, R., & Sun, Y. (2020). Effects of foreign direct investment on carbon emissions: Evidence from China and its Belt and Road countries. *Journal of Environmental Management*, *276*, 111321. https://doi.org/10.1016/j.jenvman.2020.111321

Mongelli, I., Tassielli, G., & Notarnicola, B. (2006). Global warming agreements, international trade and energy/carbon embodiments: An input–output approach to the Italian case. *Energy Policy*, *34*(1), 88–100. https://doi.org/10.1016/j.enpol.2004.06.004

Oates, W. E., & Schwab, R. M. (1988). Economic competition among jurisdictions: Efficiency enhancing or distortion inducing? *Journal of Public Economics*, *35*(3), 333–354. https://doi.org/10.1016/0047-2727(88)90036-9

Ogawa, H., & Wildasin, D. E. (2009). Think locally, act locally: Spillovers, spillbacks, and efficient decentralized policymaking. *American Economic Review*, *99*(4), 1206–1217. https://doi.org/10.1257/aer.99.4.1206

Qi, X., Han, Y., & Kou, P. (2020). Population urbanization, trade openness and carbon emissions: An empirical analysis based on China. *Air Quality, Atmosphere & Health*, *13*(5), 519–528. https://doi.org/10.1007/s11869-020-00808-8

Qian, Y., & Roland, G. (1998). Federalism and the soft budget constraint. *American Economic Review*, *88*(5), 1143–1162. http://www.jstor.org/stable/116864

Qian, Y., & Weingast, B. R. (1996). China's transition to markets: Market-preserving federalism, Chinese style. *The Journal of Policy Reform*, *1*(2), 149–185. https://doi.org/10.1080/13841289608523361

Rehman, A., Ma, H., Ahmad, M., Irfan, M., Traore, O., & Chandio, A. A. (2021). Towards environmental sustainability: Devolving the influence of carbon dioxide emission to population growth, climate change, forestry, livestock and crops production in Pakistan. *Ecological Indicators*, *125*, 107460. https://doi.org/10.1016/j.ecolind.2021.107460

Ren, S., Liu, Z., Zhanbayev, R., & Du, M. (2022). Does the internet development put pressure on energy-saving potential for environmental sustainability? Evidence from China. *Journal of Economic Analysis*, *1*(1), 81–101.

Shahbaz, M., Balsalobre-Lorente, D., & Sinha, A. (2019). Foreign direct Investment–CO2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption. *Journal of Cleaner Production*, *217*, 603–614. https://doi.org/10.1016/j.jclepro.2019.01.282

Shahbaz, M., Gozgor, G., Adom, P. K., & Hammoudeh, S. (2019). The technical decomposition of carbon emissions and the concerns about FDI and trade openness effects in the United States. *International Economics*, *159*, 56–73. https://doi.org/10.1016/j.inteco.2019.05.001

Shan, Y., Guan, D., Zheng, H., Ou, J., Li, Y., Meng, J., Mi, Z., Liu, Z., & Zhang, Q. (2018). China CO2 emission accounts 1997–2015. *Scientific Data*, *5*(1), 1–14. https://doi.org/10.1038/sdata.2017.201

Shu, C., Xie, H., Jiang, J., & Chen, Q. (2018). Is urban land development driven by economic development or fiscal revenue stimuli in China? *Land Use Policy*, *77*, 107–115. https://doi.org/10.1016/j.landusepol.2018.05.031

Su, C. W., Umar, M., & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote renewable energy consumption? Analyzing the role of political risk. *The Science of the Total Environment*, *751*, 142220. https://doi.org/10.1016/j.scitotenv.2020.142220

Sun, Y., Guan, W., Razzaq, A., Shahzad, M., & An, N. B. (2022). Transition towards ecological sustainability through fiscal decentralization, renewable energy and green investment in OECD countries. *Renewable Energy*, *190*, 385–395. https://doi.org/10.1016/j.renene.2022.03.099

Tiebout, C. M. (1956). Exports and regional economic growth: Rejoinder. *Journal of Political Economy*, *64*(2), 169–169. https://doi.org/10.1086/257773

Tufail, M., Song, L., Adebayo, T. S., Kirikkaleli, D., & Khan, S. (2021). Do fiscal decentralization and natural resources rent curb carbon emissions? Evidence from developed countries. *Environmental Science and Pollution Research International*, *28*(35), 49179–49190. https://doi.org/10.1007/s11356-021-13865-y

Van Der Kamp, D., Lorentzen, P., & Mattingly, D. (2017). Racing to the bottom or to the top? Decentralization, revenue pressures, and governance reform in China. *World Development*, *95*, 164–176. https://doi.org/10.1016/j.worlddev.2017.02.021

Wang, Y., Liao, M., Wang, Y., Xu, L., & Malik, A. (2021). The impact of foreign direct investment on China's carbon emissions through energy intensity and emissions trading system. *Energy Economics*, *97*, 105212. https://doi.org/10.1016/j.eneco.2021.105212

Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., & Xiong, D. (2020). The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP 21 Agreements? *Journal of Environmental Management*, *271*, 111027. https://doi.org/10.1016/j.jenvman.2020.111027

Wang, L. O., Wu, H., & Hao, Y. (2020). How does China's land finance affect its carbon emissions? *Structural Change and Economic Dynamics*, *54*, 267–281. https://doi.org/10.1016/j.strueco.2020.05.006

Wang, M., Xu, M., & Ma, S. (2021). The effect of the spatial heterogeneity of human capital structure on regional green total factor productivity. *Structural Change and Economic Dynamics*, *59*, 427–441. https://doi.org/10.1016/j.strueco.2021.09.018

Wellisch, D. (1995). Locational choices of firms and decentralized environmental policy with various instruments. *Journal of Urban Economics*, *37*(3), 290–310. https://doi.org/10.1006/juec.1995.1015

Wildasin, D. E. (1996). Introduction: Fiscal aspects of evolving federations. *International Tax and Public Finance*, *3*(2), 121–135. https://doi.org/10.1007/BF00399906

Wu, H., Hao, Y., & Ren, S. (2020). How do environmental regulation and environmental decentralization affect green total factor energy efficiency: Evidence from China. *Energy Economics*, *91*, 104880. https://doi.org/10.1016/j.eneco.2020.104880

Wu, H., Li, Y., Hao, Y., Ren, S., & Zhang, P. (2020). Environmental decentralization, local government competition, and regional green development: Evidence from China. *The Science of the Total Environment*, *708*, 135085. https://doi.org/10.1016/j.scitotenv.2019.135085

Wu, R., Ma, T., & Schröder, E. (2022). The contribution of trade to production-Based carbon dioxide emissions. *Structural Change and Economic Dynamics*, *60*, 391–406. https://doi.org/10.1016/j.strueco.2021.12.005

Wu, L., Sun, L., Qi, P., Ren, X., & Sun, X. (2021). Energy endowment, industrial structure upgrading, and CO2 emissions in China: Revisiting resource curse in the context of carbon emissions. *Resources Policy*, *74*, 102329. https://doi.org/10.1016/j.resourpol.2021.102329

Yang, X., Wang, J., Cao, J., Ren, S., Ran, Q., & Wu, H. (2022). The spatial spillover effect of urban sprawl and fiscal decentralization on air pollution: Evidence from 269 cities in China. *Empirical Economics*, *63*(2), 847–875. https://doi.org/10.1007/s00181-021-02151-y

You, D., Zhang, Y., & Yuan, B. (2019). Environmental regulation and firm eco-innovation: Evidence of moderating effects of fiscal decentralization and political competition from listed Chinese industrial companies. *Journal of Cleaner Production*, *207*, 1072–1083. https://doi.org/10.1016/j.jclepro.2018.10.106

Yuan, Z., Xu, J., Li, B., & Yao, T. (2022). Limits of technological progress in controlling energy consumption: Evidence from the energy rebound effects across China's industrial sector. *Energy*, *245*, 123234. https://doi.org/10.1016/j.energy.2022.123234

Zhang, Z., Gao, X., Zhang, S., Gao, H., Huang, J., Sun, S., Song, X., Fry, E., Tian, H., & Xia, X. (2022). Urban development enhances soil organic carbon storage through increasing urban vegetation. *Journal of Environmental Management*, *312*, 114922. https://doi.org/10.1016/j.jenvman.2022.114922

Zhang, D., & Hussain, H. I. (2021). Nexus between fiscal imbalance and emissions reduction: New evidence from developing economies. *Journal of Environmental Management*, *297*, 113360. https://doi.org/10.1016/j.jenvman.2021.113360

Zhang, Y. J., Liu, Z., Zhang, H., & Tan, T. D. (2014). The impact of economic growth, industrial structure and urbanization on carbon emission intensity in China. *Natural Hazards*, *73*(2), 579–595. https://doi.org/10.1007/s11069-014-1091-x

Zhang, L., Nian, Y. W., & Liu, J. J. (2018). Land market fluctuations and local government debts: Evidence from the municipal investment bonds in China. *China Economic Quarterly*, *3*, 1103–1126. https://doi.org/10.13821/j.cnki.ceq.2018.04.11

Zhang, K., Zhang, Z. Y., & Liang, Q. M. (2017). An empirical analysis of the green paradox in China: From the perspective of fiscal decentralization. *Energy Policy*, *103*, 203–211. https://doi.org/10.1016/j.enpol.2017.01.023

Zhao, J., Jiang, Q., Dong, X., Dong, K., & Jiang, H. (2022). How does industrial structure adjustment reduce CO2 emissions? Spatial and mediation effects analysis for China. *Energy Economics*, *105*, 105704. https://doi.org/10.1016/j.eneco.2021.105704

Zheng, C., Deng, F., Zhuo, C., & Sun, W. (2022). Green credit policy, institution supply and enterprise green innovation. *Journal of Economic Analysis*, *1*(1), 28–51.