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Local governments competing for the environment and green innovation-evidence from China

Journal of Applied Economics

Provided in Cooperation with: University of CEMA, Buenos Aires

Suggested Citation: Wan, Kai (2024) : Local governments competing for the environment and green innovation-evidence from China, Journal of Applied Economics, ISSN 1667-6726, Taylor & Francis, Abingdon, Vol. 27, Iss. 1, pp. 1-20, https://doi.org/10.1080/15140326.2024.2358723

This Version is available at: https://hdl.handle.net/10419/314275

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Journal of Applied Economics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/recs20

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To cite this article: Kai Wan (2024) Local governments competing for the environment and green innovation-evidence from China, Journal of Applied Economics, 27:1, 2358723, DOI: 10.1080/15140326.2024.2358723

To link to this article: https://doi.org/10.1080/15140326.2024.2358723

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Published online: 24 May 2024.

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Local governments competing for the environment and green innovation-evidence from China

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ABSTRACT

Enhancing green innovation is the key to realizing high-guality development and the "dual-carbon" goal. This paper takes the data from Chinese cities from 2000 to 2018 as a sample to test the impact and mechanism of local governments' competition for the environment on urban green innovation. The study found that local government competition for the environment can effectively promote urban green innovation, and the spatial spillover effect is significant and can lead neighboring cities to improve the level of green innovation jointly. The results of the mechanism test indicate that local government competition promotes green innovation through two channels: influencing fiscal expenditure bias and the establishment of development zones. Further analysis shows that the impact of government competition on green innovation has apparent spatial heterogeneity, while the double-threshold effect results in an "N"-shaped relationship between local government competition and urban green innovation.

ARTICLE HISTORY

Received 8 September 2023 Accepted 16 May 2024

KEYWORDS

Environmental decentralization: fiscal spending bias; development zone creation; theoretical models

1. Introduction

China's economy has led the global economic recovery after the 2008 global financial crisis, and as of 2023, China's manufacturing value-added ranked first in the world for 13 consecutive years (Lo Re et al., 2023). However, the energy-intensive rising pattern of poor efficiency has brought several issues, including resource depletion and environmental deterioration (Alder et al., 2016). The reason for this is that local governments have prioritized economic growth as their primary goal ever since the fiscal decentralization system was implemented in 1994, resulting in a model of competition where "GDP" is the keystone, which has therefore caused an "emphasis on growth at the expense of the environment." The "growth over environment" phenomenon has resulted from this. The report of the Twentieth Party Congress proposes accelerating the green transformation of the mode of development, promoting the greening and decarbonization of economic and social development, and accelerating the research and development and popularization and application of advanced energy-saving and carbon-reducing technologies. As a fusion of "green development" and "innovation drive", green technological innovation is the core

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driving force and a key link in balancing ecological resources and the environment, contributing to the realization of the "dual-carbon" goal and promoting sustainable economic development (Mele & Magazzino, 2020; Udeagha & Breitenbach, 2021). Under the double constraints of "energy saving and emission reduction" and "dual carbon" targets, the performance evaluation index system of Chinese local government officials has also been adjusted from the traditional "GDP" as the baton of the competition mode gradually tilted in the direction of the environment. So how does it affect urban green innovation in a context where local governments compete for the environment? And through what mechanisms? This series of questions is significant to China's efforts to reach the "dual carbon" target, stimulate green technology innovation, and realize the win-win ecological and economic benefits situation.

Green technological innovation has been one of the important topics discussed in the economics literature in the last two decades. Established studies have explored the critical factors affecting green technological innovation, mainly regarding FDI, industrial agglomeration, financial development, and the digital economy (Li et al., 2023; Magazzino, 2023). Regarding the study of the relationship between local government competition and the environment, the established studies focus on the following three areas of discussion: The first branch of literature analyzes the impact of fiscal decentralization and environmental regulation on green technological innovation from two dimensions, arguing that decentralization brought about by fiscal decentralization as well as inter-governmental competitive behaviors will lead to shortsighted behaviors of local governments towards the ecological environment. For example, DiLiddo et al. (2018) argue that competition among local governments in pursuit of economic growth has a significant race-to-the-bottom effect on environmental pollution and that this effect will worsen as the level of fiscal decentralization increases (Kunce & Shogren, 2008). Böcher (2012) measures eco-efficiency using Chinese provincial-level panel data from 1998-2013 and finds that fiscal decentralization leads to a decline in eco-efficiency with significant spatial spillovers in the eastern and western regions. Konisky (2007) similarly points out that local governments tend to compete at the bottom of the barrel regarding environmental regulation, which could be more conducive to environmental improvement. The second strand of the literature explores the core conditions affecting regional green innovation and the mechanisms of their interaction. It argues that government competition can help play the "helping hand" role and significantly promote green innovation. Nie et al. (2022) pointed out that local governments can enhance green innovation by formulating corresponding environmental regulation policies to restrain enterprises. The greater the intensity of environmental regulation, the more it can force enterprises to improve their green innovation technology, thus realizing a win-win situation for economic development and environmental protection. Frondel's et al. (2007) study also supports the idea that local governments can positively influence firms' green technological innovations by strengthening environmental regulations. Little literature has explored the impacts and mechanisms of green innovation from the perspective of local governments competing for the "environment". The third strand of literature suggests that factors such as market competition, level of economic development, and industrial structure may shape the relationship between local government competition and green innovation (Jiang et al., 2023; Magazzino et al., 2022) and that local government behavior that does not match the factor endowment of the city in which it is located may have an indeterminate effect on green innovation, which in turn leads to a government competition for the environment has a nonlinear relationship with green technology innovation efficiency (Xu et al., 2022).

It is easy to find that the existing literature on local government competition and green technological innovation has conducted a preliminary discussion. However, there are still certain areas for improvement. First, the existing research is mainly concerned with the local government because the growth of competition has led to changes in environmental regulatory behavior, thus impacting the ecological environment and green innovation. However, as China gradually enters the stage of high-quality development, and the assessment system of local governments is gradually changing from "GDP" to equal emphasis on economy and environment, the existing studies are insufficient to discuss the changes in environmental regulatory behaviors of local governments for the sake of environmental competition, as well as the cascading effects of green innovation in cities. Second, the research perspective is single; the existing literature is mainly from the perspective of information asymmetry, focusing on the vertical inter-governmental relations between the central and local governments, and the discussion on the horizontal interaction between governments needs to be more profound. It is necessary to analyze the strategic choices caused by the horizontal interaction of governments based on vertical inter-governmental relations. Thirdly, the research object needs to be more comprehensive, and the existing research favors the provincial level and pays less attention to the city level. In contrast, analyzing green technological innovation from the city level has more accurate decision-making value.

Given this, this paper uses data from 285 prefecture-level cities in China from 2000 to 2018 to test the relationship between local governments' competition for the environment and urban green innovation. They are considering that under the traditional GDP appraisal system, local governments often focus on infrastructure investment to win the appraisal advantage, and underinvest in people's livelihoods, which is not conducive to the enhancement of the level of green innovation (Zhang & Zou, 1998). Where local governments compete for the "environment", local fiscal spending preferences change, affecting green innovation (Udeagha & Ngepah, 2023). At the same time, the establishment of development zones, as one of the essential means for local governments to promote investment attraction and industrial agglomeration, may be affected by changes in the appraisal system of government officials in charge, affecting green innovation in cities.

The marginal contributions of this paper are as follows: First, this paper examines the forms of local governments' competition for the "environment", which is more conducive to the portrayal of local governments' strategic behaviors in the context of the construction of a beautiful China, and provides new explanations for the relationship between local governments and green innovation. Second, this paper illustrates the impact of local governments' competition for the "environment" on green innovation by constructing a mathematical model and analyzing its mechanism from the dimensions of fiscal expenditure bias and the establishment of development zones, which makes up for the shortcomings of the existing literature, which is mainly illustrated through logical reasoning. Finally, this paper matches the data from the State Intellectual Property Office (SIPO) with the Green Patent Classification Number (GPCN) standard published by the World Intellectual Property Office (WIPO) to obtain the city's green patent data, which

in turn serves as a measure of green innovation, not only avoiding the errors arising from the previous reliance on the measurement of green innovation but also providing empirical evidence at the city level.

2. Theoretical foundations and assumptions

This section draws on Acemoglu et al. (2012) environmental technological progress to mathematically deduce the effect of local government competition for the environment on the efficiency of green innovation. Assuming local representative enterprises i, in the context of China's particular socialist situation, the objectives of enterprises are not only to maximize their profits, but also to take into account the relationship between government and enterprises, and the actions of local governments often influence enterprises' decisions. Under the influence of the local government, this paper considers that the firm's objective balances profit maximization and output and sets the firm's objective function as:

$$\mathbf{U} = \rho Y_i + (1 - \rho) \Pi_i \tag{1}$$

This paper draws on Hsieh and Klenow's (2009) approach of setting the market as a monopolistically competitive structure and assuming that the output of representative firms satisfies the Cobb-Douglas production function.

$$Y_i = A_i K_i^{\alpha} L_i^{\beta} \tag{2}$$

Where Y_i is the output of the representative firm, K_i is capital, L_i is labor, and $\alpha + \beta = 1$, the representative firm, is characterized by constant returns to scale. Firms produce externalities in addition to their products, in the following functional form.

$$G(Y_i) = \theta(A_i) A_i K_i^{\alpha} L_i^{\beta}$$
(3)

 $\theta(A_i)$ denotes the green innovation capability of a representative firm. The stronger the green innovation capability of an enterprise, the lower the output of polluting goods. Firms' technological innovation is positively correlated with green innovation, i.e., $\frac{\partial \theta(A_i)}{\partial A_i} > 0$. Since the production of products by representative enterprises leads to environmental pollution, local governments usually adopt taxation as a means of environmental regulation of enterprises to mitigate this negative externality, and we assume that the environmental tax rate set by local governments is τ .

The probability of R&D success of a firm is related to local infrastructure (Acemoglu et al., 2016), which usually depends on the fiscally biased spending of the local government. Therefore, this paper assumes that the probability of a firm's R&D success is a function of the local government's fiscally biased spending, denoted as H(F), with $\frac{\partial H(F)}{\partial F}$ >0, representing that the more the local government's fiscally biased spending, the greater the probability of a firm's R&D success. If the firm is successful in its R&D, it can have a market share of ψ . Assuming that consumer spending is C, the government levies a tax rate of t. In this paper, the costs of capital and labor used by a representative firm are denoted by r and w, respectively, the profit function is as follows.

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$$\mathbf{E}(\Pi) = \mathbf{H}(\mathbf{F})(1-\mathbf{t})\boldsymbol{\psi}\mathbf{C} - \mathbf{r}K_i - \mathbf{w}\mathbf{L}\mathbf{i} - \tau\mathbf{G}(Y_i) \tag{4}$$

Assumption 2, according to the local government objective function, this paper considers the case where the local government competes for the environment. Meanwhile, local governments will also pursue local revenue N. Given this, the objective function of local governments is set as follows.

$$V_1 = Y_i + \mathcal{N} \tag{5}$$

$$V_2 = \delta Y_i + (1 - \delta) \mathbf{G}(Y_i) + \mathbf{N}$$
(6)

Where $N=t\psi CH(F)+\tau G(Y_i)$, δ denotes the preferences of local governments between output and environmental pollution.

By constructing a two-stage game between enterprises and local governments, it is considered that local governments have a first-mover advantage in playing the game with representative enterprises, choosing fiscal bias and the intensity of environmental regulation to maximize their utility. The representative enterprises consider the local government's choice in their decision-making. Therefore, this paper adopts the inverse solution method and considers the choice of representative enterprises first.

Substituting equation (4) into equation (1), we obtain.

$$\mathbf{U} = \rho A_i K_i^{\alpha} L_i^{\beta} + (1 - \rho) [\mathbf{H}(\mathbf{F})(1 - \mathbf{t}) \boldsymbol{\psi} \mathbf{C} - \mathbf{r} K_i - \omega L_i - \tau \mathbf{G}(Y_i)]$$
(7)

Constructing the Lagrangian function such that equation (7) finds the first-order partial derivatives for K_i and L_i , respectively, gives

$$\frac{\partial \mathbf{U}}{\partial K_i} = \alpha \rho A_i K_i^{\alpha - 1} L_i^{\beta} + (1 - \rho) \left(-\mathbf{r} - \tau \alpha \theta(A_i) A_i K_i^{\alpha - 1} L_i^{\beta} \right)$$
(8)

$$\frac{\partial \mathbf{U}}{\partial L_i} = \beta \rho A_i K_i^{\alpha} L_i^{\beta - 1} + (1 - \rho) \left(-\mathbf{r} - \tau \beta \theta(A_i) A_i K_i^{\alpha} L_i^{\beta - 1} \right)$$
(9)

Combining equations (8) and (9) with the constraint that the representative firm's profit is positive, we obtain expressions for K_i and L_i due to $\alpha + \beta = 1$.

$$K_{i} = \frac{\mathrm{H}(\mathrm{F})(1-\mathrm{t})\psi\mathrm{C}}{r + \frac{\mathrm{w}\beta}{\alpha} + \tau\theta(A_{i})A\left(\frac{\beta}{\alpha}\right)^{\beta}}$$
(10)

$$L_{i} = \frac{\beta(\mathbf{H}(\mathbf{F})(1-\mathbf{t})\psi\mathbf{C}}{r\alpha + \omega\beta + \tau\theta(A_{i})A\left(\frac{\beta}{\alpha}\right)^{\beta}}$$
(11)

Substituting equations (10) and (11) into (2) yields.

$$Y_{i} = \frac{A_{i} \mathbf{H}(\mathbf{F})(1-\mathbf{t}) \psi \mathbf{C} \left(\frac{\beta}{\alpha}\right)^{\beta}}{r + \frac{\mathbf{w}\beta}{\alpha} + \tau \theta(A_{i}) A \left(\frac{\beta}{\alpha}\right)^{\beta}}$$
(12)

Further, by substituting equation (12) into (3), the green innovation efficiency of the firm is obtained as.

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$$\theta(A_i) = \frac{A_i H(F)(1-t) \psi C\left(\frac{\beta}{\alpha}\right)^{\beta} - \frac{w\beta}{\alpha} Y_i - rY_i}{Y_i \tau A_i \left(\frac{\beta}{\alpha}\right)^{\beta}}$$
(13)

Substituting (12) into the local government's objective functions (5) and (6) respectively gives.

$$V_{2} = \delta \frac{A_{i}H(F)(1-t)\psi C\left(\frac{\beta}{\alpha}\right)^{\beta}}{r+\frac{w\beta}{\alpha}+\tau\theta(A_{i})A\left(\frac{\beta}{\alpha}\right)^{\beta}} + (1-\delta)*\frac{\theta(A_{i})A_{i}H(F)(1-t)\psi C\left(\frac{\beta}{\alpha}\right)^{\beta}}{r+\frac{w\beta}{\alpha}+\tau\theta(A_{i})A\left(\frac{\beta}{\alpha}\right)^{\beta}} + t\psi CH(F) + \tau\frac{\theta(A_{i})A_{i}H(F)(1-t)\psi C\left(\frac{\beta}{\alpha}\right)^{\beta}}{r+\frac{w\beta}{\alpha}+\tau\theta(A_{i})A\left(\frac{\beta}{\alpha}\right)^{\beta}}$$
(14)

Let V_2 be partial derivative with respect to $\theta(A_i)$, F and τ respectively.

$$\frac{\partial \mathrm{V2}}{\partial \theta(A_i)} = \frac{\tau A_i \mathrm{H}(\mathrm{F})(1-\mathrm{t}) \psi \mathrm{C}\left(\frac{\beta}{\alpha}\right)^{\beta} (1-\delta) A\left(\frac{\beta}{\alpha}\right)^{\beta})}{\left(r + \frac{\mathrm{w}\beta}{\alpha} + \tau \theta(A_i) A\left(\frac{\beta}{\alpha}\right)^{\beta}\right)^2} > 0 \tag{15}$$

$$\frac{\partial \mathrm{V1}}{\partial \mathrm{F}} = \frac{A_i \frac{\partial H(F)}{\partial F} (1-t) \psi \left(\frac{\beta}{\alpha}\right)^{\beta} (1+\tau \theta(A_i))}{r + \frac{\mathrm{w}\beta}{\alpha} + \tau \theta(A_i) A \left(\frac{\beta}{\alpha}\right)^{\beta}} + \mathrm{t}\psi \mathrm{C}\frac{\partial H(F)}{\partial F} > 0$$
(16)

Based on equation (15), we formulate Hypothesis 1.

H1: Local government competition for the environment can significantly promote the level of green innovation.

Further let V_1 be partial derivative with respect to F Since $\frac{\partial H(F)}{\partial F} > 0$ we get: here find V_2 .

$$\frac{\partial V_2}{\partial \tau} = \frac{A_i H(F)(1-t) \psi C\left(\frac{\beta}{\alpha}\right)^{\beta} \left[\theta(A_i) \left(r + \frac{w\beta}{\alpha} - \delta(1-\delta) A\left(\frac{\beta}{\alpha}\right)^{\beta}\right)\right]}{\left(r + \frac{w\beta}{\alpha} + \tau \theta(A_i) A\left(\frac{\beta}{\alpha}\right)^{\beta}\right)^2}$$
(17)

Local government competition plays a vital role in attracting resources by setting up development zones to attract investment, and the rapid growth of development zones has been achieved due to competition between local governments. According to the 2018 China Development Zone Audit and Announcement Catalog, as of the end of 2018, there were a total of 1991 provincial-level development zones. Based on the 294 prefecture-level cities nationwide, the average number of development zones per prefecture-level city amounts to 6.7 provincial-level development zones, which are agglomeration-driven and provide the appropriate platform for firms to promote innovation investment,

thereby enhancing the efficiency of green innovation in cities and achieving high-quality development. Local governments compete through the zone channel and thus influence the efficiency of green innovation. We propose the following hypothesis based on the conclusions of equations (16) and (17).

H2: Local governments compete for the environment by influencing green innovation through fiscal spending bias and the creation of development zones.

3. Research methods

3.1. Data

Due to the severe lack of data in areas such as Turpan and Linyi, these cities were excluded, resulting in a final sample of 5,415 from 285 cities. The data of urban green patents were obtained from the classification standards of SIPO and WIPO. The data source for development zones is "Catalog of China's Development Zones Audit and Announcement (2018 Edition)", and other data is from "China Urban Statistical Yearbook" of past years. The statistical software used in the empirical part of this paper is Stata 15, and the software used in the map part is ArcMap 10.1. Missing values are filled in by interpolation.

3.2. Model

To consider the impact of local government competition on urban green innovation, this paper draws on C. Y. Liu et al. (2022). It introduces the interaction term between local government competition and environmental regulation as the core explanatory variable and the level of urban green innovation as the explanatory variable. The model as shown in equation (18) is constructed:

$$INN_{it} = \alpha_0 + \alpha_1 lComp_{it} * IER_{it} + \alpha X_{it} + u_i + u_i + v_t + \varepsilon_{it}$$
(18)

Where INN_{it} is the level of green innovation in the city i in year t. $IComp_{it}^* IER_{it}$ is the core explanatory variable. X_{it} denotes the control variable and α_0 is the intercept term. Coefficient α_1 is the local government competition regression coefficient, α is the control variable regression coefficient, v_i is the city fixed effect, ε_{it} is the time fixed effect.

To test for spatial spillover effects, this paper constructs a spatial Durbin model (19).

$$INN_{it} = \alpha_0 + \alpha_1 lComp_{it} * IER_{it} + \beta_1 \sum_{i \neq j} w_{ij} lComp_{it} * IER_{it} + \alpha X_{it} + \beta \sum_{i \neq j} w_{ij} X_{it} + u_i$$

+ $v_t + \varepsilon_{it}$ (19)

In this, a geographic distance weight matrix is constructed to test for correlation and an economic spatial weight matrix for robustness.

Further, we construct a threshold panel data model with Comp-ER as the threshold variable to verify the nonlinear relationship: as shown in equation (20).

 $INN_{it} = \alpha_0 + \alpha_1 lComp_{it} \cdot lER \cdot I(Comp_{it} \cdot ER < \delta_1) + \alpha_2 lComp_{it} \cdot lER \cdot I(\delta_1 \le Comp_{it} \cdot ER < \delta_2) + \alpha_2 lComp_{it} \cdot lER \cdot I(Comp_{it} \cdot ER > \delta_2) + \phi lX_{it} + \varepsilon_{it}$

(20)

3.3. Variable selection

Green Innovation (*INN*). Considering that green patent data can better respond to green innovation in cities, this paper draws on Nie et al. (2022) and selects the patent database searched by the Property Rights Office of the State Intellectual Property Office from 2000–2018, which contains filtering information such as the application number, disclosure number, invention name, applicant, filing date, IPC classification number, etc., in the advanced search of the database. According to the "Green List of International Patent Classification" launched by the World Intellectual Property Organization (WIPO) in 2010, which aims at facilitating the retrieval of patent information related to environmentally friendly technologies, and based on the patent classification number of the State Intellectual Property Office (SIPO), the number of green patent applications filed by the city each year is matched and identified to be accounted for, which is further differentiated into green invention patents (*INNA*) and green utility model patents (*INNB*) as a core indicator of the city's green innovation activities.

Local Government Competition (*lComp*). Local government competition is the central explanatory variable of this paper. We use the regional FDI share of GDP as a proxy variable for local government competition (Kis-Katos & Sjahrir, 2017). Environmental regulation (*IER*). We refer to the results of Dasgupta et al. (2001). The use of "average wage" as a proxy variable for environmental regulation also suggests that the degree of environmental regulation is endogenously determined by income levels, with higher income levels leading to stricter environmental regulation and lower income levels leading to less stringent environmental regulation. In addition, the local government competition in each city for the consideration of environmental factors, to strengthen the government performance appraisal, this paper refers to the practice of Liu et al. (2022) and further introduces the local government competition and environmental regulation interaction term examination (*lComp*IER*).

Fiscal expenditure bias (*lexpend*): Due to the reform of government revenue and expenditure classification in 2007, some fiscal revenue and expenditure classification accounts were abolished and combined, such as infrastructure expenditure, transportation expenditure and business and industrial expenditure, etc., which were not set up as separate subaccounts, resulting in the unavailability of data for some accounts. which uses the proportion of local general budget expenditure net of expenditure on people's livelihood to local general budget expenditure. The expenditure on people's livelihood includes education expenditure, social security and employment expenditure, and health care and family planning expenditure (Czarnitzki et al., 2011).

A number of development zones (*lZone*). Development zone data is compiled from the 2018 National Development Zone Review and Announcement Catalog (2018 edition) for each city development zone data plus 1 to take the logarithm.

Due to the large number of factors affecting urban green innovation, to try to avoid endogeneity problems due to the omission of variables, this paper is the same as Yu

Variable	Obs	Mean	Std. Dev.	Min	Max
INNA	5,415	2.6276	1.9063	0.0000	9.5432
INNB	5,415	2.9926	1.8292	0.0000	8.8901
IComp	5,415	0.0879	1.3743	-5.8710	4.3500
IER	5,415	10.1426	0.7360	2.2834	12.6780
lexpand	5,415	0.4755	0.0530	0.0232	0.6757
IZone	5,415	1.3297	0.8044	0.0000	3.7377
lCul	5,415	3.4304	0.8839	0.0000	8.3722
llnf	5,415	9.3508	1.1867	5.1428	12.9257
lInd	5,415	3.6071	0.2606	2.1401	8.3282
llnt	5,415	3.1957	1.2969	0.0000	8.5516
lhum	5,415	10.0512	1.5184	3.4012	13.9108

Table 1. Descriptive statistics.

Organized through Stata15 software.

et al. (2023), and the control variables selected in this paper are as follows: (1) Regional literacy level (lCul), measured by the number of books in public libraries per 100 people in each region, treated logarithmically. (2) Infrastructure development (lInf), measured by social fixed asset investment per capita, is treated logarithmically. (3) Industrial structure (lInd), measured by the proportion of value added in the tertiary sector to GDP in each city, logarithmically. (4) Information technology level (lInt), measured by the number of internet users in each city, logarithmically. (5) Human capital level (lhum), measured by the number of university students per 10,000 students, logarithmically.

To present a comprehensive picture of each variable, the descriptive statistics of the relevant variables designed in the paper are shown in Table 1.

4. Analysis of results

4.1. Return to baseline

The estimation results of the base regression are shown in Table 2. Among them, INNA and INNB are green invention patents and green utility patents, respectively, as the explanatory variables of the model. Model (1) considers only local government environmental competition, and the estimated coefficient on the interaction term between local government and environmental regulations is positive after considering environmental factors. Model (2) adds control variables to model (1) and the estimated coefficient on local government competition remains significantly positive. Local government competition, taking into account environmental factors, still significantly increases the level of green innovation in cities after controlling for other influences. Models (3) and (4) changed the explanatory variable to utility green patents and found that the estimated coefficient of local government competition did not change in nature and remained significantly positive. Taken together, this suggests that local government competition for the sake of the environment is conducive to improving urban green innovation. Because of this, hypothesis H1 is confirmed. This also corroborates Udeagha and Muchapondwa's (2023) argument that horizontal competition among local governments around the environment has a significant innovation effect.

	IN	NA	IN	NB
Variables	Model (1)	Model (2)	Model (3)	Model (4)
IComp*IER	0.125***	0.123***	0.088***	0.088***
	(14.92)	(14.53)	(12.32)	(12.24)
ICul	-	0.209***	-	0.187***
		(8.31)		(8.77)
llnf	-	-0.059**	-	0.006**
		(-2.45)		(0.29)
llnd	-	-0.074	-	0.029
		(-1.15)		(0.54)
llnt	-	0.093***	-	0.100***
		(3.97)		(5.04)
lhum	-	0.091***	-	0.098***
		(3.81)		(4.84)
FE Time	YES	YES	YES	YES
FE City	YES	YES	YES	YES
Cons	5.645***	3.848***	4.774***	2.061***
	(11.52)	(5.78)	(11.45)	(3.65)
Obs	5414	5415	5416	5415
Adj-R ²	0.804	0.808	0.836	0.840

****, ***, **denote significant levels at 1%, 5%, 10% respectively; t-values in brackets. Same remarks as in the table below.

4.2. Spatial correlation analysis

We find that the Moran indices for green invention patents, utility patents, and local government competition are significantly positive over the sample period, which can be empirically tested using a spatial econometric model. Based on Figure 1, In terms of the spatial distribution of green innovation, the spatial distribution characteristics show two features: First, the green innovation capacity of eastern cities is better than that of central and western cities. Based on the unique regional advantages of the coast, the eastern cities



Figure 1. Left: green patents for inventions, Right: green patents for practical applications.

are the engines and stabilizers of China's economic development, and play an exemplary and driving role in industrial transformation and institutional innovation. Second, the green innovation capacity of key cities has formed a "multi-point multi-pole" regional spatial distribution. The key regional cities are mainly concentrated in cities in the Bohai Rim, the Yangtze River Delta, and the Guangdong, Hong Kong, and Macao Bay Area. Due to the policy advantages, strong economic development base, and high level of culture, education science, and technology of the cities in this region, the green innovation level of the "multi-point and multi-pole" cities is remarkable.

As can be seen from Figure 2, under the traditional model of local governments competing around economic growth, local governments often lack the motivation and capacity to manage the ecological environment, and due to the existence of spillover effects and the "pollution shelter" effect, this model of competition will cause local governments to reduce their investment in the environment, thus making regional economic growth mostly at the expense of the environment. Especially for the traditional resource-dependent cities in central China, there is excessive and irrational competition among local governments, which triggers a GDP race and creates a "growth miracle", but also pays a high ecological and environmental price. After local governments take environmental factors into account, the horizontal competition of local governments is gradually tilted towards the environment, leading to the flow of resources in each city also in the direction of green innovation and other directions, which leads to a change in both the mode of competition and the choice of strategies of local governments. This is consistent with the findings of Yang et al. (2020).

The spatial Durbin model takes into account the general form of the spatial lag model and spatial error model, which not only reflects the correlation situation of the independent variables but also explores the autocorrelation relationship with the independent



Figure 2. Left: without the environment, Right: with the environment.

		//	NNA				NNB	
		Deco	Decomposition Model			Deco	omposition Mo	odel
Variables	Durbin Models	Direct effects	Indirect effects	Total effect	Durbin Models	Direct effects	Indirect effects	Total effect
IComp*IER	0.067***	0.075***	0.242***	0.317***	0.044***	0.050***	0.1760***	0.226***
	(7.78)	(8.69)	(7.73)	(10.15)	(6.00)	(6.75)	(6.92)	(8.92)
W*IComp*IER	0.116***	-	-	-	0.092***	-	_	-
	(5.55)				(5.27)			
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
FE Time	YES	YES	YES	YES	YES	YES	YES	YES
FE City	YES	YES	YES	YES	YES	YES	YES	YES
Obs	5415	5415	5415	5415	5415	5415	5415	5415
Adj-R ²		0	.797			0.	822	

Table	3. Interactive	e effects of loca	l government	competition	and environment	al regulation.

variables and the dependent variable in neighboring regions, so this paper selects the spatial Durbin model as a subsequent empirical econometric analysis.

In this paper, local government competition interacts with environmental regulations to show that local governments compete for the environment, and the regression results are shown in Table 3. From the empirical results, it can be seen that the coefficients of the impact of local government competition for the environment on urban green innovation are all significantly positive. The estimated coefficient of the main effect and spatial spillover effect of the interaction between local government competition and environmental regulation are both positive, indicating that incorporating environmental factors into the evaluation system can enhance the level of urban green innovation by local governments. The same conclusion can be obtained from the spatial decomposition model. This point is in line with Deng et al. (2019) study findings are consistent. We believe the possible reason is that the local government officials in charge are tilting their limited resources towards enhancing the level of green innovation in the city, and thus the level of green innovation, to obtain promotions, especially under the new assessment mechanism. The results of this paper further show that this positive environmental impact is not only reflected in the city but also has a significant spatial spillover effect, which can significantly pull the level of green innovation in neighboring cities, which is a useful extension of the existing research.

4.3. Robustness tests

Replacing the weight matrix. To test the results of the basic regression, we replace an economic matrix with a weight matrix, and the results are shown in Table 4, where it can be found that the main regression coefficients and the spatial spillover coefficients are positive and pass the 1% significance level, which indicates that the local governments' competition for the environment not only promotes the local level of green innovation but at the same time, has a spillover effect on the level of green innovation of the neighboring regions. This is consistent with the basic regression results.

Replacement of core explanatory variables. To ensure the robustness of the results, this paper adopts the total number of urban green patent applications as a proxy variable for green innovation level (*INN*) to strengthen the conclusions of the underlying regression.

		IN	INNB					
	Durbin	Deco	mposition N	lodel	Durbin	Deco	mposition N	1odel
Variables	Models	Direct	Indirect	Total	Models	Direct	Indirect	Total
IComp*IER	0.108***	0.107***	0.093***	0.201***	0.081***	0.081***	0.053***	0.135***
	(12.92)	(12.47)	(4.28)	(8.94)	(11.43)	(11.12)	(5.70)	(6.55)
W*IComp*IER	0.101***	-	-	-	0.049***	-	-	-
	(4.41)				(6.52)			
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
FE Time	YES	YES	YES	YES	YES	YES	YES	YES
FE City	YES	YES	YES	YES	YES	YES	YES	YES
Obs	5415	5415	5415	5415	5415	5415	5415	5415
Adj-R ²		0.704				0.730		

Table 4. Interactive effects of local government competition and environmental regulation.

	Table 5.	Estimation	results	of	replacing	explanatory	/ variables
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		INN					
	Durbin		Decomposition Mode	I			
Variables	Models	Direct	Indirect	Total			
IComp*IER	0.189***	0.179***	0.148***	0.336***			
	(14.55)	(14.12)	(4.22)	(9.29)			
W*IComp*IER	0.149***	-	-	-			
	(4.15)						
Control variables	YES	YES	YES	YES			
FE Time	YES	YES	YES	YES			
FE City	YES	YES	YES	YES			
Obs	5415	5415	5415	5415			
Adj-R ²		C).612				

The regression results are reported in Table 5. It can be found that local governments competing for the environment not only promote the level of green innovation in their regions, but also have beneficial effects on neighboring regions.

Excluding special samples. Since Beijing, Shanghai, Tianjin, and Chongqing are equivalent to provincial units, to avoid the impact of sample error, we re-test the municipalities after excluding them. The regression results are shown in Table 6, and it can be found that the main regression coefficient and the spatial spillover coefficient are both positive and pass the 1% significance level, indicating that the local governments' competition for the environment not only promotes the local level of green innovation but also has a spillover effect on the level of green innovation in the neighboring regions. This is consistent with the basic regression results.

		IN	NA		INNB				
	Durbin	Deco	mposition N	lodel	Durbin	Deco	mposition N	lodel	
Variables	Models	Direct	Indirect	Total	Models	Direct	Indirect	Total	
IComp*IER	0.056***	0.065***	2.363***	2.428***	0.038***	0.044***	1.345***	1.389***	
	(6.38)	(7.30)	(3.88)	(3.98)	(5.16)	(5.82)	(3.83)	(3.96)	
W*IComp*IER	0.405***	-	-	-	0.260***	-	-	-	
	(6.97)				(6.52)				
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	
FE Time	YES	YES	YES	YES	YES	YES	YES	YES	
FE City	YES	YES	YES	YES	YES	YES	YES	YES	
Obs	5339	5339	5339	5339	5339	5339	5339	5339	
Adj-R ²		0.776				0.802			

Table 6. Estimation results excluding special samples.

Variables	INNA (1)	INNB (2)
IComp*IER*IExpend	0.052***	0.036***
	(4.86)	(4.01)
W*IComp*IER*IExpend	0.096***	0.062***
	(3.27)	(2.58)
Control variables	YES	YES
FE Time	YES	YES
FE City	YES	YES
Obs	5415	5415
Adj-R ²	0.783	0.821

Table 7. Tests for fiscal spending bias interaction effects.

Table	8.	Tests	for	development	area	interaction
effects						

Variables	INNA	INNB
IComp*IER*IZone	0.008***	0.005***
	(8.98)	(7.15)
W*IComp*IER*IZone	0.009***	0.009***
	(4.12)	(4.56)
Control variables	YES	YES
FE Time	YES	YES
FE City	YES	YES
Obs	5415	5415
Adj-R ²	0.791	0.820

4.4. Channel inspection

The results of the model including fiscal spending deviation are shown in Table 7, Model (1) and Model (2). Both the main regression coefficient and the spatial spillover coefficient are found to be significantly positive, indicating that the fiscal expenditure deviation channel not only has a significant positive impact on regional green innovation, but also has a significant spatial spillover to neighboring cities. Local governments compete to improve green innovation by expanding fiscal spending bias. Replacing the explanatory variables regression results remain consistent.

As can be seen from Table 8, the coefficient of the interaction term of local government competition for the environment and development zones is significantly positive, and the coefficient of its spatial spillover effect is also significantly positive and we believe that local government competition for the environment through the channel of development zones not only has an impact on local green innovation, but also has a positive impact on the green innovation in other regions. The results of replacing the explanatory variables with utility-based green patents as in Table 3 have significantly positive main effect coefficients and spatial spillover effect coefficients, suggesting that the process of influencing the level of green innovation through the channel of development zones as a result of the competitive environment of the local government is strong, and the competitive environment of the local government influences the level of green innovation in the city through the establishment of development zones.

	INNA			INNB			
Variables	Eastern	Centre	Western	Eastern	Centre	Western	
IComp*IER*IZone	0.007***(5.63)	0.001	0.006***(5.22)	0.003***	0.001	0.004***	
		(0.45)		(2.99)	(1.30)	(4.75)	
W*IComp*IER*IZone	0.005	0.015***	-0.005*(-1.74)	-0.003	0.010***	0.006***(2.57)	
	(1.50)	(4.72)		(-0.97)	(3.76)		
Control variables	YES	YES	YES	YES	YES YES		
FE Time	YES	YES	YES	YES	YES	YES	
FE City	YES	YES	YES	YES	YES	YES	
Obs	0.759	0.781	0.668	0.700	0.820	0.813	

Table 9. Tests for heterogeneity in development areas.

5. Further analysis

To examine the heterogeneity of development zone establishment mechanisms across different regions, the sample is further analyzed according to three sub-samples of eastern, central, and western cities. The regression results are shown in Table 9. The development zones interacted with the regional city dummy variable. From the empirical tests, it is concluded that the development zone channel in the eastern cities significantly increases the level of urban green innovation compared to the cities in the central and western regions. Further grouping the fiscal expenditure bias by eastern, central, and western China, the results show that eastern cities have a significantly higher level of green innovation in the fiscal expenditure bias channel compared to central and western cities (Liu et al., 2021). Our study is consistent with the findings of Wang et al. (2022). Realizing different environmental regulation intensities for different regions will be more conducive to the level of green innovation in cities due to the variability of financial and development zones in different regions.

The model further examines the mechanisms of environmental regulation influencing urban green innovation by considering local government competition for the environment. The regression results are shown in Table 10. The results of the threshold test show that the single threshold passes the significance test at the 1% level when the interaction term between local government competition and environmental regulation is used as the threshold variable and the explanatory variable is green patents for inventions. The triple threshold did not pass the significance test. By replacing the explanatory variable green patents for inventions with green patents for utilities, the double threshold still exists. Using the interaction term between local government competition and environmental regulation as the threshold, the study shows that the effect of local government competition for the environment on urban green innovation is "N" shaped. Local government

Threshold			F-statistic		Confidence interval			
Variables	variables	Number of thresholds	Threshold	values	Significance	10%	5%	1%
Invention	IComp*IER	Single threshold	2213.416***	54.38	0.000	19.251	21.243	28.603
of green		Double Threshold	2201.509**	29.18	0.060	24.173	31.549	51.293
patents		Three-fold threshold	2193.222	20.39	0.203	26.660	36.563	45.719
Practical	IComp*IER	Single threshold	1645.267***	33.54	0.007	16.646	20.489	26.349
green		Double Threshold	1640.008*	17.30	0.077	16.215	18.144	23.701
patents		Three-fold threshold	1635.945	13.40	0.343	21.943	26.275	35.888

Table 10. Threshold model parameter estimates.

competition for the environment has a non-linear relationship with the level of green innovation being promoted and then suppressed, with overly stringent environmental policies increasing production costs and crowding out green innovation inputs.

6. Discussion

First, in contrast to Yang et al. (2020) conclusion that local government competition in China makes achieving energy efficiency and emission reduction difficult, this paper finds that a novel model of local government competition around the environment can effectively enhance urban green innovation. Not only that, this paper also through the construction of the spatial Durbin model found that the green innovation effect induced by local government for environmental competition has an obvious spatial spillover effect, and can effectively drive the neighboring cities to take the road of green development together, which is a useful expansion of the research of Y. Xu et al. (2023). Second, given the distinct Chinese characteristics of local governments' horizontal competition tools, this study further reveals that local governments' fiscal expenditure bias and development zone establishment behavior are important mechanisms through which local governments compete for the environment leading to a significant increase in urban green innovation. Third, unlike the findings of Chen et al. (2022), which discuss the heterogeneity of local government behavior only from the perspective of temporal persistence, this paper first explores the different performance characteristics of the two mechanisms of government fiscal expenditure bias and development zone establishment from the perspective of geographic location, which is a useful addition to the existing studies. In addition, using the interaction term between local government competition and environmental regulation as a threshold, this paper finds that the effect of long-term local government competition for the environment on urban green innovation is "N" shaped.

Future research can expand on this foundation. First, this study used a large amount of data for empirical analysis at the city level to explore the role of local governments competing for the environment and the logic behind it, but it did not introduce key cases for specific analysis. Future studies can conduct in-depth investigations by questionnaire surveys and in-depth interviews, targeting representative governments and enterprises, in order to provide more detailed empirical evidence of the impact of local government competition on green innovation. Second, due to the limitations of data and related policies, this paper does not deeply explore the impact of the characteristics of principal government officials in exploring the impact of local government competition on green innovation, and future research can further analyze the heterogeneous impacts of principal government officials' tenure experience, gender characteristics, and so on, on green innovation.

7. Conclusions and policy recommendations

The traditional mode of economic development has resulted in increasingly severe environmental pollution, and the contradiction between economic development and the ecological environment has become increasingly prominent. As the world's largest carbon emitter, China has committed to the international community to achieve peak carbon emissions by 2030 and carbon neutrality by 2060. The government attaches great importance to this, constantly improving the ecological and environmental protection policy and administrative agency management system, and promoting green innovation as an essential way to improve the ecological environment and achieve regional low-carbon transformation. To explore how environmental decentralization affects green innovation under environmental regulation, we conduct an empirical analysis of Chinese cities. We find that (1) local governments' competition for the environment has a significant positive effect on green innovation, and there is a significant spatial spillover effect that can drive green innovation in neighboring cities. (2) The results of the mechanism test show that local governments significantly promote urban green innovation by adjusting fiscal expenditure bias and establishing development zones to compete for the environment. (3) Further analysis reveals that geographic location characteristics can significantly influence the effect of local government competition and that the mechanism of setting up development zones in which local governments compete for the environment impacts green innovation, which is more significant in the eastern region. In the long run, a significant N-shaped relationship between local government competition for the environment and urban green innovation. The research in this paper helps to improve the level of urban green innovation and provides theoretical references for local governments to formulate policies. Based on the results of this study, we propose the following policy recommendations.

First, the assessment and incentive system must be improved, and multi-dimensional target management must be established. The Chinese government should further enhance the proportion of environmental factors in the assessment system of local governments, find a balance between economic and environmental assessment indicators, and establish perfect incentives and penalties to effectively bring into play the role of local governments in promoting urban green innovation for environmental competition. Secondly, the design of the assessment system for local governments to compete for the environment should fully consider the differences in financial expenditure preferences and the establishment of urban development zones. Based on summarizing the experience of developed regions, it is prudent to promote the construction of a new type of inter-governmental relationship of horizontal "competition", thus forming public interests among local governments and realizing a cross-regional cooperative network for environmental pollution control and green technology innovation. Third, target pressure management is implemented according to local conditions. The results of this paper show that the eastern region performs well, while local governments in the central and western regions do not have a significant role in promoting urban green innovation around environmental competition. The eastern coastal areas as the local government performance appraisal reform front-runner, fully Kahui its advantageous position with the role of driving, for the western, northeastern and other serious dependence on traditional resources of the city, in the supervision of the local government target management at the same time can be appropriately reduced environmental constraints, increase policy support, "attracting capital" and "attracting talent" and give equal weight to. In addition, at this stage, China should continue to guide local governments to shift from "economic competition" to "innovation competition" and "green competition", and from "competition" to "collaboration", to effectively prevent the diminishing marginal effect of local government competition on urban green innovation.

Acknowledgments

We are very grateful to the journal reviewers for their valuable comments on the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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