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Research Article

Calculation of Urban Green Competitiveness and Analysis of Spatial and Temporal Evolution Characteristics in China

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Abstract

It is particularly important to analyze the influencing factors of urban green competitiveness and the spatial distribution characteristics under the constraint of carbon emissions. The research ideas of this paper: firstly, this paper selects the carbon emission intensity and urban green competitiveness data in 2010, 2013, 2015, 2018 and 2020 for panel data regression; secondly, this paper applies a variety of methods to carry out the robustness test, and the results show that the regression model is better, and analyzes the development of urban green competitiveness for the heterogeneity of large cities and small cities; subsequently, the use of inverse geographic matrix to analyze the spatial correlation between the global Moran index and local Moran index for urban green competitiveness, and to analyze the spatial and temporal pattern evolution of urban green competitiveness. The conclusions of the study show that, from the viewpoint of influencing factors, carbon emission intensity presents a significant negative effect on the development of urban green competitiveness, and has a greater impact on the green competitiveness of large cities than that of small cities. From the perspective of spatial correlation, urban green competitiveness presents positive spatial correlation and shows a growing trend over time. Finally, this paper puts forward relevant policy recommendations based on the findings of the study.

Keywords

Carbon Intensity, Urban Green Competitiveness, Panel Regression Model, Moran Index

1. Introduction

In the process of carbon emission reduction, it is inevitable to be accompanied by a huge transformation of the city's industrial structure shift, technological progress and population employment, etc., so it is important to explore the combined impact of achieving the carbon peaking and carbon neutrality goals on cities, in order to more efficiently explore and adjust the path of carbon emission reduction, and to achieve the carbon peaking and carbon neutrality goals in a higher quality. The GDP indicator is one of the most commonly used indicators among the existing measurement indicators, but due to the failure to take into account environmental and welfare impacts, the evaluation of the indicator has some bias. Therefore, this paper tries to construct a new indicator to evaluate the comprehensive level of the city's economy, society, and environment, which is of great significance in adjusting the path of carbon emission reduction in a timely manner.

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2. Literature Review

The level of urban green competitiveness embodies the concept of sustainable development, and the level of urban green competitiveness reflects the quality level of urban development from the side, which is one of the key indicators to measure the quality of urban green development, and the higher the level of urban green competitiveness, the higher the quality of urban green development. Urban green competitiveness stems from the concept of urban competitiveness. Regarding the concept of urban competitiveness, some scholars point out that urban competitiveness refers to the ability of a city to attract, own, control and transform resources, to compete for, occupy and control the market to create value and to provide welfare for its inhabitants compared with other cities in the process of competition and development. [1] Urban competitiveness is an extremely important reference for cities to recognize their own development and learn from the development experience of other cities, and it also helps to generate a reasonable competitive relationship between cities and promote the coordinated development of regional economy. However, with the accelerated process of urbanization, some irreversible environmental problems have arisen in the process of pursuing economic development in cities, and cities have begun to pay attention to the promotion of urban development in a more sustainable way, so more and more scholars have begun to pay attention to the development of green competitiveness of cities, and have gradually taken into account the contradiction between environment and economic development, [2] Most of the existing literature focuses on the evaluation system of urban green competitiveness and the study of urban green development efficiency. [3-4] Regarding the measurement of urban green competitiveness, some scholars have centered on the index measurement and spatial analysis of the green competitiveness of the three major urban agglomerations. [5] Regarding the results of the urban green development efficiency, the relevant scholars believe that the city size has a significant impact on the urban green development efficiency presents a nonlinear impact, [6] and the green development efficiency of Chinese cities presents a fluctuating and rising state. [7] With the increasing prominence of resource and environmental issues, the barriers to improving regional green competitiveness show spatial variability and specificity depending on the degree of the barriers. [8].

More studies on carbon emissions take urban carbon emission intensity as the research object, and existing scholars mainly analyze the influencing factors of urban carbon emission intensity, [9] the influence of digital economy on carbon emission intensity, [10] and the influence of pilot policies of low-carbon cities and other policies on carbon emission intensity. [11] Qiu S et al. [12] pointed out that low-carbon city pilot policies can achieve green growth through mechanisms such as promoting technological innovation, optimizing industrial structure, and improving resource allocation efficiency. Lan T et al. (2023) [13] pointed out that compact urban forms, both physical and functional, help to reduce carbon emissions in cities. In addition, the proportion of tertiary industry output to GDP, the proportion of energy consumption to GDP, the level of green technology innovation in cities, and the proportion of industrial soot emissions to GDP are the main factors to improving the competitiveness of Beijing-Tianjin-Hebei cities in terms of urban green and low-carbon development. [14]

While the research on carbon emission and urban green competitiveness is relatively less, the existing literature is less explicitly put forward the concept of urban green competitiveness, mostly focusing on the concepts of green city as well as the efficiency of urban development, but in fact there is a crossover with the meaning of urban green competitiveness put forward in this paper, Shi C et al. [15] defined urban resilience as economic prosperity, social well-being, and clean environment, and analyzed the carbon emission reduction on these three dimensions, and analyzed the impact mechanism of carbon emission reduction on these three dimensions, and concluded that carbon emission reduction is positively correlated with urban resilience from 2006 to 2019, and high resilience and high carbon emission reduction are spatially clustered. The concept of urban green competitiveness in this paper is similar to the connotation of urban resilience proposed by it, but the concept of urban green competitiveness is more comprehensive by dividing it into four dimensions and taking into account the meaning of the dimensions of education and resources. Li J et al. [16] pointed out that the total carbon emissions of 249 cities were in the stage of rapid development in the period of 1996-2017, and that under the constraints of carbon emissions, urban development efficiency showed fluctuations and did not increase significantly. Wang Z et al. [17] pointed out that green development is a more comprehensive, integrated consideration of economic, ecological and social issues, the study concluded that the pilot policy of green and low-carbon cities by encouraging the growth of the digital economy, which in turn promotes the green development of the city. From the viewpoint of the sub-indicators of urban green competitiveness, the social welfare and inequality issues in the process of carbon emission have gradually received attention from scholars in recent years. Jia Z et al. [18] pointed out that the carbon neutral target negatively affects urban-rural inequality. Chen H et al. [19] pointed out that the process of carbon emission reduction inevitably leads to the transformation of economic structure, industrial structure and energy structure, which will bring about a dramatic changes in economic output, employment, etc., thus affecting overall social welfare and equity. By constructing a dynamic optimization model to explore the carbon emission path to achieve carbon neutrality under the framework of integration of welfare, equity and the environment, and pointed out that with the increasingly stringent constraints on carbon emission reduction, the cost of emission reduction would be increased accordingly, but the overall social welfare would be slightly increased. Zhang Z et al. [20] studied the resource utilization efficiency in relation to the quality of regional development, and concluded that the overall resource utilization efficiency in the mid-east shows an upward trend, but inter-regional imbalance is the main source of spatial imbalance, and there is a different degree of decoupling between resource utilization efficiency and high-quality development indexes in each province due to redundancy of inputs such as resources and environmental functions.

For the influence factors of urban green development competitiveness, Scholars have demonstrated the impact of 13 influencing factors on regional green competitiveness through relevant literature and questionnaires, and six principal components have been extracted as environmental protection, sustainable, low carbon, ecological, bad and health factors, which can be seen that the low carbon factor has a certain influence on urban green competitiveness. [21] And also scholars explored the impact of environmental policy innovation on urban green competitiveness in China. [22] In addition, there are differences in the impact of low-carbon policies on urban green development between different cities in the east, middle and west, and there is polarization from the east to the west. [23] The scholars studied the relationship between carbon emission efficiency and urban green innovation, explored the spatial and temporal evolution of carbon emissions and urban green innovation, and used the Spatial Durbin Model to study the impacts and driving factors of green innovation on carbon emissions, and the results showed that there is a positive impact of green innovation on the efficiency of urban carbon emissions. The effect of emission reduction will vary according to the regional economy and green innovation capacity. [24]

There is little literature on the evaluation of urban development, and most of the evaluation dimensions are relatively thin, while the green competitiveness of this paper comprehensively considers the economic, social, resource and environmental dimensions in the process of urban development, and most of the literature treats the intensity of urban carbon emissions as an dependent variable variable, and less of it considers the intensity of urban carbon emissions as an independent variable variable to analyze its impact on a certain aspect. And the existing literature on urban green competitiveness is more in the evaluation point of view, and there are fewer studies on the effect of practicing the carbon peaking and carbon neutrality goals on the level of urban green competitiveness. Then, under the constraint of carbon peaking and carbon neutrality goals, what kind of comprehensive impact on urban green competitiveness has been produced, whether it is possible to realize the coordinated development of carbon emission reduction and the city's economic base and scientific and technological progress, natural assets and environmental pressure, resource and environmental efficiency, as well as the policy effect and social welfare, and whether there are regional differences and what kind of characteristics are presented in the spatial distribution of urban green competitiveness. The clarification of these issues is of great significance to facilitate the coordinated development of carbon peaking and carbon neutrality goals and urban green competitiveness.

Therefore, based on the previous research results, this paper takes 281 prefecture-level cities and above as the research object, firstly, establishes the evaluation indexes of urban green competitiveness from the four dimensions of economic foundation and scientific and technological progress, natural assets and environmental pressure, resource and environmental efficiency, urban policy response and social welfare; Secondly, analyzes the role of the carbon emission intensity in influencing the urban green competitiveness through empirical evidence; Subsequently, analyzes the spatial correlation of urban green competitiveness by using the Moran index. Finally, the conclusions of this paper are revealed and relevant suggestions are put forward for the promotion of urban green competitiveness. By analyzing the influencing factors of urban green competitiveness and the evolution of its spatial correlation, this paper can help to promote the green and high-quality development of cities, promote the innovation of urban development mode, and promote the coordinated green development among regions.

3. Empirical Analysis of the Impact of Carbon Emissions on Urban Green Competitiveness

3.1. Model Settings

In order to test the role of carbon emissions in influencing the green competitiveness of cities, this paper uses panel data to set up the model as follows:

$$UGC_{it} = \beta_0 + \beta_1 CI_{it} + \beta_2 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

In equation (1), i represents prefecture-level city, t represents year, UGC_{it} represents the green competitiveness of the urban i in period t, CI_{it} is the carbon emission intensity of the city i in period t, X is the aggregation of control variables, μ_i is the individual fixed effect, δ_t is the time fixed effect, and ε_{it} is the random error term of the model.

3.2. Description of Variables

(1) Dependent variables (lnUGC)

As mentioned in the first chapter of the report, the urban green competitiveness evaluates the green competitiveness of Chinese cities through four dimensions, following the five principles of logic, scientificity, representativeness, the principle of comparability and accessibility to form the green competitiveness index system of Chinese cities, which includes four first-level indexes, eight second-level indexes and 37-third-level indexes, and limited by the availability of indicator data, this paper only measures the data of urban green competitiveness in 2010, 2015 and 2020, and derives the data of urban green competitiveness through the evaluation of the above indicators, and the subsequent measurement and analysis report supplements the data of urban green competitiveness in 2013 and 2018 with the interpolation method using the stata software.

***Table 1**. Indicator Evaluation System.*

Level 1 indicators	Secondary indicators	Tertiary indicators	
Economic base and scientific and technological progress	Economic base	1. GDP per capita	2. Regional revenues
		3. Labor productivity in the primary sector	4. Labor productivity in the secondary sector
		5. Labor productivity in the tertiary sector	6. Share of tertiary sector value added
	Science and technology education	7. Proportion of science and technology investment in public expenditure	8. Number of scientists and technicians per 10,000 employees
		9. Ratio of investment in education to public expenditure	10. Number of university students per 10,000 population
Natural assets and environmental stress	Resource reserve	11. Cultivated land area per capita	12. Water resources per capita
		13. Green space per capita	14. Forest cover rate
	Environmental stress	15. Sulfur dioxide emissions per unit of land area	16. Sulphur dioxide emissions per capita
		17. Chemical oxygen demand emissions per unit land area,	18. Chemical oxygen demand per capita
		19. NOx emissions per unit of land area	20. NOx emissions per capita
		21. Ammonia nitrogen emissions per unit of land area	22. Ammonia emissions per capita
Resource and environmental efficiency	Resource efficiency	23. Water consumption per unit of GDP	24. Comprehensive industrial solid waste utilisation rate
	Environmental efficiency	25. Sulfur dioxide emissions per unit of GDP	26. Chemical oxygen demand emissions per unit of gross regional product
		27. NOx emissions per unit of GDP	28. Ammonia nitrogen emissions per unit of GDP
Policy effects and social welfare	Environmental investment and governance	29. Expenditures on energy conservation and protection as a share of fiscal expenditures	30. Investment in urban appearance and environmental sanitation accounts for the proportion of fixed asset investment in municipal public facilities construction.
		31. Public transportation vehicles per 10,000 population	32. Urban wastewater treatment rate
		33. Non-hazardous treatment rate of domestic waste	
	Quality of life	34. Per capita disposable income of urban residents	35. Average sales price of commercial property
		36. Greening coverage in built-up areas	37. Number of days with air quality above level 2

After selecting the indicators, the "extreme difference standardization method" is used to distinguish the positive and negative characteristics of the correlation between the indicators and the green competitiveness of cities to measure the green competitiveness index of Chinese cities. If it is a positive indicator, i.e., the larger the value of the indicator, the more conducive to the formation and development of urban green competitiveness, then the formula for standardization of the indicator is:

$$X_i = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

If it is a reverse indicator, i.e., the larger the value of the indicator, the more detrimental it is to the formation and development of the urban green competitiveness, the indicator is first positively normalized, i.e., the maximum value of the indicator is used to subtract the indicator, and subsequently, it is normalized by the following formula:

$$X_i = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

Where, X_i is the value after standardization; x_i is the original value of the indicator; x_{min} is the minimum value of the sample; x_{max} is the maximum value of the sample.

(2) Core independent variables (lnCI)

Carbon emission intensity is derived by calculating the proportion of urban carbon emissions to the GDP of the city [25], and urban carbon emission intensity, as a relative amount of indicators, can more reasonably reflect the actual changes of urban green carbon emissions.

(3) Control variables.

In order to reduce the potential impact of omitted variables on the model, it is also necessary to control other possible influencing factors other than the core independent variable carbon emission intensity. Referring to the existing literature, industrial structure, whether it is a green city or not, financial self-sufficiency rate, the average wage of employees and foreign direct investment are selected as the control variables of the model.

1) Industrial Structure Upgrading Index (IS). Industrial structure upgrading reflects the transformation from traditional high energy-consuming and low value-added industries to low energy-consuming and high value-added industries, which is the improvement of labor productivity and a key factor for cities to realize green transformation, and industrial structure upgrading can promote the advanced development of the tertiary industry, which can help to improve the level of urban green competitiveness. [26] This paper refers to the industrial structure level coefficients of each province, [27] and assigns different coefficients to different industries to illustrate the level of industrial structure upgrading in each city. The measurement formula is $IS = \sum_{i=1}^{3} y_i \times i = y_1 \times 1 + y_2 \times 2 + y_3 \times 3$, where y_i is the share of value added of i sector.

2) Green Cities (GC). The development of urban green competitiveness cannot be separated from the guidance of policies, on the one hand, in 2010, the National Development and Reform Commission issued the Notice on the Pilot Work of National Low-Carbon Cities, identifying some low-carbon pilot areas, and since then, the pilot scope of low-carbon cities has further increased in 2012 and 2017; on the other hand, the Ministry of Ecology and Environment actively promotes the creation of national ecological civilization construction demonstration cities, which plays a certain policy guidance role in the urban green development. Therefore, this paper determines whether a city is a green city by setting whether it is a low-carbon pilot city and whether it is an ecological civilization construction demonstration city or county, and a policy-guided green city helps to enhance its green competitiveness. For being a model city and county for ecological civilization construction or being a national low-carbon pilot city, the setting is 1, and vice versa, it is 0.

3) Financial self-sufficiency (lnFin). Government financial expenditure mainly comes from local revenue and government transfer expenditures, the city financial self-sufficiency rate can to a certain extent reflect the government's degree of financial control, the higher the degree of control, may help to improve the government to promote the city's green development of the capital investment, and thus improve the level of urban green competitiveness. The calculation of this indicator refers to Chen Shuo, [28] who measured the financial autonomy of local governments through the city government's general budget revenue/general budget expenditure.

4) Average salary of employees (lnSalary). For the development of urban green competitiveness is more closely linked, the higher the average salary of employees, the higher the relative income of residents, with the increase in the consumption level of urban residents, to a certain extent, the residents of the environmental awareness will be higher, the quality of consumption and living environment will put forward higher requirements. Therefore, the average salary of employees is selected as one of the control variables.

In this paper, 281 prefecture-level cities and above in China (Chaohu, Bijie, Tibet and other cities have more missing data, so they are deleted) in 2010, 2013, 2015, 2018 and 2020 are taken as the object of analysis, and the sources of data are China Urban Statistical Yearbook, China Regional Economic Statistical Yearbook, and the CSMAR database, The missing data were filled in by searching each city's statistical bulletin and interpolation, and the variables were logarithmized in consideration of reducing the variance of the data and other reasons. The descriptive statistics of the variables are shown in Table 2:

Table 2. *Descriptive Statistical Analysis of Data.*

Variable	Obs	Mean	Std. Dev.	Min	Max
lnUGC	1405	.404	.036	.262	.577
lnCI	1405	.337	.253	.027	4.536
GC	1405	.248	.432	0	1
IS	1405	.445	.148	0	1
lnFin	1405	.362	.151	.056	1.005
lnSalary	1405	.263	.091	0	.693
FDI	1405	.017	.018	0	.198

3.3. Econometric Tests

3.3.1. Benchmark Model Regression

The estimation method of panel data is mainly two kinds of fixed effects and random effects, this paper through the Hausman test, the results show that the original hypothesis is rejected at the 1% level, therefore, this paper at the same time consider the city's individual fixed effects and time fixed effects using a two-way fixed effects on the model regression, the regression results are shown in the table below.

Table 3*. Benchmark Regression Results.*

	(1)	(2)
	lnUGC	lnUGC
lnCI	-0.0095***	-0.0046*
	(-3.4008)	(-1.7547)
GC	0.0073***	0.0047***
	(5.6137)	(3.8748)
IS	0.0280***	-0.0316***
	(3.4996)	(-3.6044)
lnFin	-0.0162*	-0.0153*
	(-1.9356)	(-1.8886)
lnSalary	0.1852***	0.0399***
	(23.7898)	(3.3901)
FDI	-0.1236***	-0.0656**
	(-3.4827)	(-2.0358)
time fixed effect	NO	YES
urban fixed effect	YES	YES
N	1405	1405
adj. R^2	0.637	0.705

t statistics in parentheses
* p < 0.1, ** p < 0.05, *** p < 0.01

According to the regression results in Table 3, it can be seen that the regression coefficient is negative, which indicates that the role of urban carbon emission intensity on urban green competitiveness shows a negative relationship and passes the test of significance at the level of 10%, so it can be concluded that the reduction of urban carbon emission intensity contributes to the enhancement of urban green competitiveness. Carbon emission intensity reflects the improvement of technology level, and the reduction of carbon emission intensity in the production process has a greater effect on the improvement of urban green competitiveness.

The sign of the impact of green cities on urban green competitiveness is significantly positive and passes the significance test of 1%, indicating that the establishment of low-carbon pilot cities and ecological civilization demonstration cities has a certain promotion effect on the enhancement of urban green competitiveness. The guiding role of the government for the city is more important, which can lead the development of greening of the city, and then improve the level of urban green competitiveness.

The influence of industrial structure upgrading index on urban green competitiveness is positive and passes the significance test at 1% level, indicating that the industrial structure is developing more and more in the direction of advanced development, and the industry is shifting from high energy-consuming and high-polluting industries to low energy-consuming and low-polluting industries, which is a sign of the transformation of the city's development mode, and the development of the advanced industrial structure and the improvement of the efficiency of the production factors help to improve urban green competitiveness.

The impact of the average salary of employees on the urban green competitiveness is positive, and passed the significance test of 1% level, the average salary of employees is one of the important factors characterizing the socio-economic development of the city. Generally speaking, the higher the income of the residents, the higher the requirements of the green living environment, the higher the demand for the consumption of green products to provide a certain degree of support for the purchasing power of green products, and the level of the urban green competitiveness will also rise with it.

The impact of FDI on urban green competitiveness is negative and passes the significance test at 5% level, indicating that the increase of FDI leads to the decline of urban green competitiveness, and the introduction of foreign capital invests more in low value-added and high energy-consuming industries, and the impact on urban green competitiveness is more negative.

3.3.2. Robustness Tests

In order to avoid the chance of regression results, this paper adopts a variety of methods to carry out robustness tests to ensure the stability of the benchmark regression results, so as to prove the content of this research paper.

(1) Lagged variables. This paper adopts the lagged two-period independent variables for regression. The regression results show that the impact of urban carbon emission intensity on urban green competitiveness with two lags is significantly negative, indicating that the regression model is more significant.

(2) Tailoring. In order to avoid the deviation of the extreme value on the regression results, this paper does the shrinking treatment at 1% and 99%, after shrinking the tail on the regression model to carry out step-by-step regression, the regression results show that the intensity of urban carbon emissions on urban green competitiveness presents a signifi-

cant negative impact, which proves that the regression model is more robust.

Table 4. *Robustness Tests.*

	without control variables	**indentation test**	**Lagged three-period explanatory variables**
	lnUGC	lnUGC	lnUGC
lnCI	-0.0117***	-0.0128***	
	(-2.9772)	(-3.3062)	
L3. lnCI			-0.0182***
			(-2.8404)
GC		0.0047***	0.0046**
		(3.8308)	(2.4847)
IS		-0.0335***	-0.0322**
		(-3.7846)	(-2.2866)
lnFin		-0.0113	-0.0248*
		(-1.3420)	(-1.9385)
lnSalary		0.0388***	0.0262
		(2.7376)	(0.8297)
FDI		-0.0727*	-0.0686
		(-1.8778)	(-1.5148)
_cons	0.3793***	0.3916***	0.4171***
	(234.2807)	(76.3345)	(40.4554)
N	1405	1405	562
adj. R^2	0.694	0.705	0.576

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

3.3.3. Heterogeneity Analysis

Divided into existing first-, second- and third-tier and other cities according to their political influence, economic development and other factors, which are useful for the development of green competitiveness of Chinese cities studied in this paper, the first-, new-, second-, third- are divided into large cities, and the fourth- and fifth-tier cities are divided into small cities, This sample classification can effectively avoid the problem of unclear city division due to the large span of years, which makes the results biased and has certain reference significance.

For small cities, it can be seen that the carbon emission intensity of small cities and their green competitiveness development presents a negative relationship, but did not pass the significance level test, presumably due to the fact that the carbon emission intensity of small cities is larger, while the level of urban green competitiveness is relatively low, the city's economic development is still in the early stage of transformation, belonging to the stage of high energy consumption and high pollution, and the government is relatively more focused on the development of urban economy, has not yet reached the governance of urban green development and formed a certain scale effect. Therefore, the impact on the development of urban green competitiveness has no significant effect.

For large cities, it can be seen that the carbon emission intensity of large cities has a negative relationship with the level of urban green competitiveness, and passes the 5% significance test. Large cities have a relatively good economic foundation, the government is more proactive for the construction of green cities and the degree of supervision is relatively strict, coupled with the public's higher awareness of environmental protection and higher requirements for a green living environment, large enterprises will consider accelerating the technological transformation to improve their green competitiveness, a combination of factors that makes the carbon intensity of the large cities significantly affect the level of urban green competitiveness.

Table 5. *Heterogeneity Test.*

	Large cities	**Small city**
	lnUGC	lnUGC
lnCI	-0.0127**	-0.0015
	(-2.0010)	(-0.4864)
GC	0.0021	0.0056***
	(1.4706)	(3.0618)
IS	-0.0087	-0.0421***
	(-0.7156)	(-3.5694)
lnFin	0.0056	-0.0310***
	(0.5596)	(-2.6687)
lnSalary	0.0811***	0.0051
	(4.7190)	(0.3281)
FDI	-0.1207***	0.0842
	(-3.9530)	(1.2905)
_cons	0.4073***	0.4131***
	(43.1496)	(59.6302)
N	600	805
adj. R^2	0.936	0.808

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4. Characterizing the Evolution of Spatial and Temporal Patterns of Urban Green Competitiveness

Moran index is an earlier method for spatial correlation analysis, in order to deeply analyze the spatial spillover effect of urban green competitiveness, this paper uses the spatial correlation analysis based on urban green competitiveness to do the Moran index in order to explore the spatial correlation of green competitiveness among cities. [29-30]

4.1. Global Spatial Autocorrelation Analysis

In this paper, we calculate the global Moran index for 281 prefecture-level cities for their urban green competitiveness with the following formula:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij})\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (2)$$

$$w_{ij} = \begin{cases} \frac{1}{|\bar{d}_i - \bar{d}_j|} \\ 0 \end{cases} \quad (3)$$

Where, n denotes the number of cities, y_i and y_j denotes the urban green competitiveness index of cities i and j, respectively, and $\bar{y}$ denotes the mean value of urban green competitiveness in the city cluster; w_{ij} is the spatial weight matrix of cities i and j. In this paper, we take the reciprocal of the geographic distance between cities to get the spatial inverse geographic matrix as the spatial weight matrix, and construct the inverse geographic distance matrix to analyze the spatial relationship between cities more reasonably, and then analyze the spatial autocorrelation of urban green competitiveness. The I value range is [-1,1], if it is (0,1), it means there is a positive spatial correlation, if it is [-1,0), it means there is a negative spatial correlation, if I= 0 means there is no spatial correlation. The table of indices of global Moran's I for urban green competitiveness is derived by stata software as shown below.

For the spatial autocorrelation test of the urban green competitiveness index in 2010, 2013, 2015, 2018 and 2020, it can be seen that in the past five years, the global Moran's I value of the overall urban green competitiveness is located in the range of (0,1], and the p-value is less than 0.01, Through the significance test, it shows that there is significant spatial autocorrelation among cities, i.e., cities with high urban green competitiveness index will produce spatial spillover effect, and their neighboring urban green competitiveness indexes are also relatively high, i.e., cities with higher urban green competitiveness indexes cluster with each other; on the other hand, cities with lower urban green competitiveness indexes have lower green competitiveness values in the neighboring cities, i.e., cities with lower urban green competitiveness indexes cluster with each other. This indicates that the local urban green competitiveness index not only receives the influence of local carbon emissions, but also the urban green competitiveness of the neighboring regions will have a certain spatial spillover effect on the local area. From the time dimension, with the increase of years, the relationship between urban green competitiveness from 2010 to 2018 shows a rising trend, which can be concluded that the correlation between urban green competitiveness is gradually strengthened over time, while 2018-2020 shows a decreasing trend, which is hypothesized to be due to the outbreak of the epidemic in 2020, the railroad transportation is temporarily halted, and the cities are isolated from one another, then the spatial correlation of urban green competitiveness has slightly decreased, which is in line with the reality.

Table 6. *Index Table of Global Moran's I for the Green Competitiveness Index of Cities.*

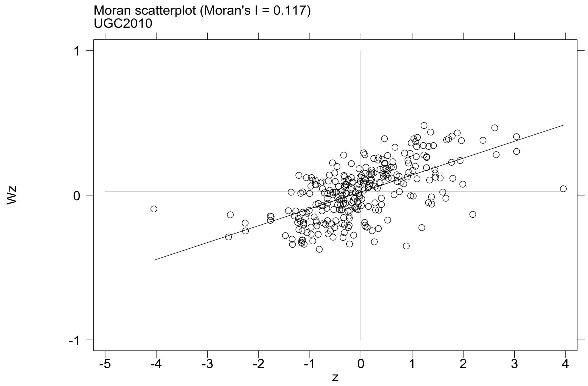
Variables	I	E(I)	sd(I)	z	p-value*
UGC2010	0.117	-0.004	0.005	23.263	0.000
UGC2013	0.123	-0.004	0.005	24.476	0.000
UGC2015	0.119	-0.004	0.005	23.861	0.000
UGC2018	0.135	-0.004	0.005	26.816	0.000
UGC2020	0.125	-0.004	0.005	24.800	0.000

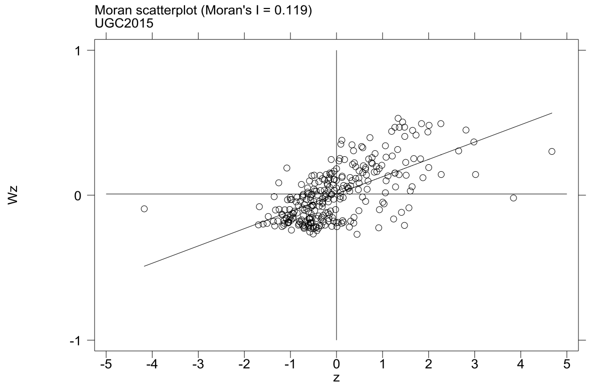
4.2. Local Spatial Autocorrelation Analysis

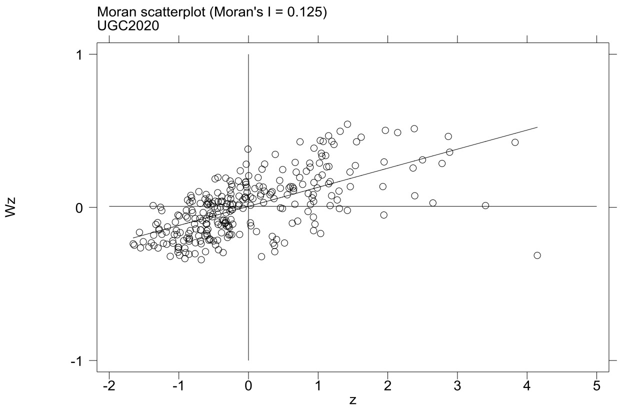
This paper further analyzes the spatial agglomeration effect or divergence effect between cities by calculating the local Moran's I in order to analyze the degree of local correlation of spatial cities, which is shown in the following formula:

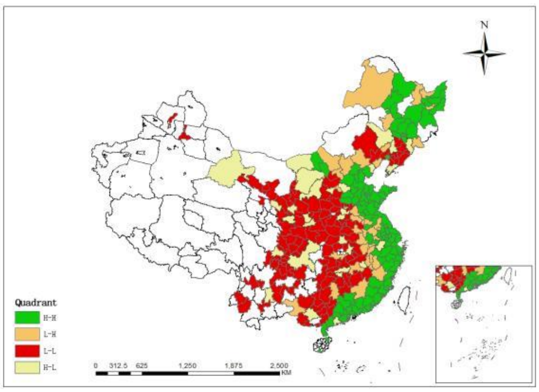
$$I = \frac{n(y_i - \bar{y})\sum w_{ij}(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (4)$$

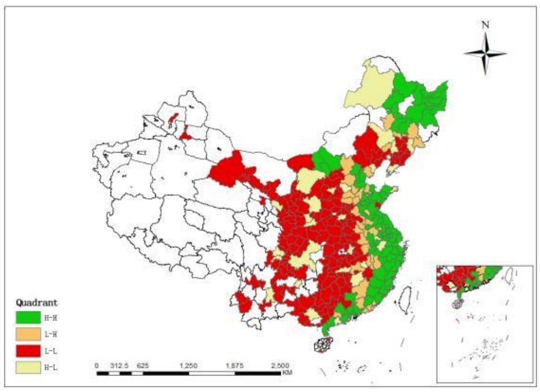
In this paper, the urban green competitiveness in 2010, 2015 and 2020 is selected for local spatial autocorrelation analysis, and a scatter plot is drawn as shown below. The horizontal axis represents the urban green competitiveness index of the region, the vertical axis represents the urban green competitiveness index of the neighboring regions, and the first quadrant is high high agglomeration, the second quadrant is low high agglomeration, the third quadrant is low low agglomeration, and the fourth quadrant is high low agglomeration. Due to the large number of sample city data, city names are omitted here to keep the overall picture intuitive. As can be seen from the figure, most cities are distributed in the first and third quadrants, which are characterized by high agglomeration and low agglomeration, among which, the cities located in the first quadrant are mainly Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin, Nanjing, Zhuhai, Zhongshan and so on, most of them are eastern cities, which indicates that the urban green competitiveness of there cities are high, and the urban green competitiveness level of the neighboring cities is relatively high, and the radiation effect of the neighboring areas is stronger. The two show a positive correlation. Cities located in the third quadrant are mainly Liupanshui City, Zigong, Ziyang, Fangchenggang, Yibin, Ya'an and other cities, mostly in the western region, whose urban green competitiveness level is relatively backward, and their neighboring regions are also relatively backward. The second quadrant is a low-high region, the main cities are Xuancheng, Chuzhou and other cities, quadrant four is its own high surrounding low region, the main cities are Chengdu, Xi'an, Changsha and Wuhan and other cities, most of the new first-tier cities or second-tier cities, presumably because the region itself is in the process of development, has not yet formed a positive radiation effect. Comparing the scatter plot of 2010 and 2020, it can be seen that Changsha, Wuhan and Qingdao are located in the fourth quadrant of the scatter plot in 2010, while they are located in the first quadrant of the scatte rplot in 2020, and the urban green competitiveness level of these cities has changed from high-low to high-high, which indicates that these cities are gradually generating a radiant effect in the course of their own greening, and have a significant positive correlation with urban green competitiveness in the neighboring regions. There is a significant positive correlation with the green competitiveness of neighboring cities.











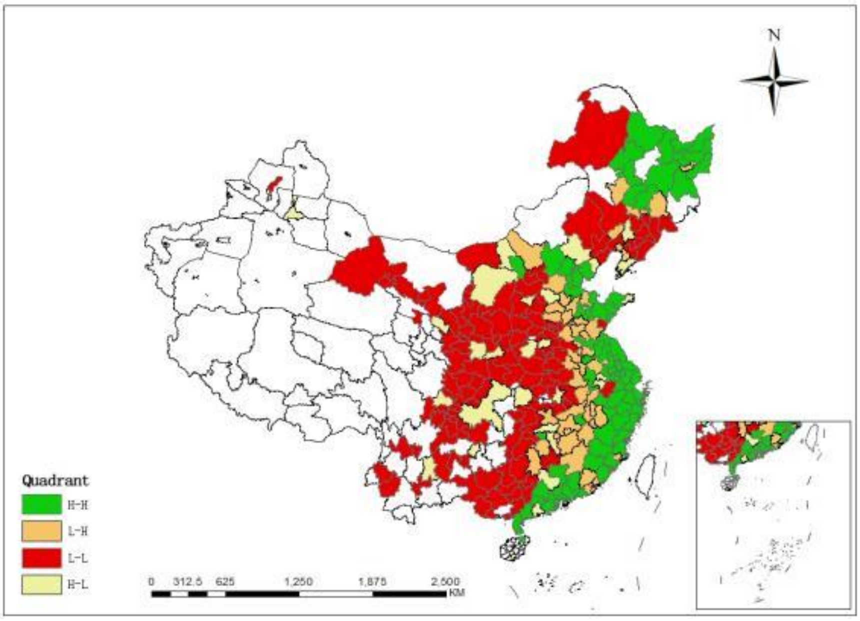


Figure 1. Moran Index Quadrant Chart for 2010, 2015 & 2020.

4.2.1. Analysis of Temporal Changes in the Local Moran Index of Urban Green Competitiveness

The above figure shows the quadrant map of urban green competitiveness Moran index in 2010, 2015 and 2020, from which it can be seen that the high and high clustering areas in the first quadrant mainly appear in the southeast coastal region, which is manifested in the spatial correlation of the development of urban green competitiveness, i.e., the cities with high green competitiveness of their own cities have high green competitiveness indexes of their neighboring cities as well. In addition, the quadrants of the Moran Index of most cities do not have significant jumps from 2010 to 2020, and the cities that have jumped from the second or third quadrant to the first quadrant, i.e., from low-high agglomeration or low-low agglomeration to high-high agglomeration, for example, Zhuhai, Shanwei, Tangshan, and Xiangtan, etc., which in spite of the low green competitiveness of their own cities or the low green competitiveness of the surrounding cities, they have gradually developed and realized the win-win situation of "high-high" for themselves and the surrounding cities. According to the indicators of urban green competitiveness, it shows that the economic base and scientific and technological progress, natural assets and environmental pressure within the cities have developed better, and these cities have gradually formed new growth poles to drive the development of the neighboring areas. At the same time, there are also some cities that are gradually falling into the third quadrant of "Low-Low", i.e., the green competitiveness of cities shows a declining trend from 2010 to 2020, such as Xianyang, Xuancheng, Nanning, Wuhai and Tonghua.

Table 7. Moran Index Quadrant Changes for Selected Cities.

City Name	Quadrant 2010	Quadrant 2015	Quadrant 2020
Tangshan	1	2	1
Ulanchab	2	1	2
Qitaihe	2	1	2
Chizhou	2	1	2
Yongzhou	2	3	2
Zhuhai	1	4	1
Shanwei	1	2	1
Heyuan	1	2	1
Yunfu	1	2	1
Haikou	1	3	1
Meishan	3	4	3
yanan	3	4	3

Table 7 shows that some cities were in the same quadrant in 2010 and 2020, but their quadrants jumped from 2010 to 2015, for example, Tangshan City was in high-high agglomeration in 2010, but changed to low-high agglomeration in 2015 and then to high-high agglomeration in 2020, which indicates that there was a certain degree of environmental degradation in the middle of the period, and then adjusted and gradually recovered to the original high-high agglomeration level. Similarly, some cities represented by Zhuhai City, which was in the first quadrant in 2010 and 2020, jumped to the fourth quadrant in 2015, indicating that the development of green competitiveness of Zhuhai City in 2015 was mainly due to the siphon effect, with its own green competitiveness developing well but the performance of the surrounding cities being poor, but after a certain period of adjustment it was still high-high in 2020. In addition, some cities represented by Meishan City were in the state of low-low agglomeration in 2010 and 2020, but it is worth noting that it jumped to the fourth quadrant in 2015 and was in the state of high-low agglomeration, which indicates that there is some progress in its own green competitiveness, However, it may not be able to sustain and exert a driving effect on the surrounding cities due to its sloppy economic development, etc. Therefore, in 2020, it will return to the original low-low agglomeration status.

4.2.2. Spatial Analysis of the Localized Moran Index of Urban Green Competitiveness

According to the distribution of Moran Index in 2020, from the perspective of east and west city regions, the high and high agglomeration areas in the first quadrant mainly appear in the southeast coastal region, which reflects that the economic foundation of the eastern region is better, the industrial structure is relatively reasonable, and the development of green competitiveness of the city is at the forefront, while the low and low agglomeration part of the third quadrant is mainly located in the central region, which has a relatively weak economic foundation and a relatively high number of energy-consuming industries and reflects that the development differences between regions still exist and have a certain impact on the development of green competitiveness. The industrial layout of the central region is relatively high energy consumption industry, and the side reflects that the development difference between regions still exists, and it has certain influence on the development of urban green competitiveness. From the perspective of urban agglomerations, Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta, Chengdu-Chongqing, and Harbin-Changsha City Circle are selected to be analyzed. Figure 2 reflects the distribution of urban green competitiveness Moran index of some city clusters, from which it can be seen that all of the Yangtze River Delta region is located in the first quadrant, indicating a high high agglomeration, indicating that the Yangtze River Delta region's city radiation effect is better, and realize the coordinated development of the inter-region, compared to the performance of the Pearl River Delta region, the majority of the cities of the Pearl River Delta region is located in the first quadrant, but there are still two cities in the fourth quadrant, and the urban green competitiveness index of the cities of the Yangtze River Delta region is the highest in the region. The green competitiveness index of the cities shows low around its own high. In the Beijing-Tianjin-Hebei region, Beijing, Tianjin and other cities are located in the first quadrant, Shijiazhuang as a potential city is located in the fourth quadrant, and Handan, Baoding and other cities are located in the second quadrant, which is low for itself and high for the surrounding cities, indicating that the siphoning effect in the Beijing-Tianjin-Hebei urban agglomeration is more obvious, and has not yet formed the driving role of the greening of the better cities. Chengdu-Chongqing region performs poorly, most of the cities are located in the third quadrant, the performance of low-low agglomeration, only Chongqing, Chengdu is located in the fourth quadrant, indicating that the Chengdu-Chongqing urban agglomeration siphon effect is larger, urban green competitiveness of Moran index is higher concentrated in the center of the city. Most cities in the Harbin-Changsha City Cluster, such as Changchun and Harbin, show high agglomeration in the first quadrant of the Green Competitiveness Moran Index, while a few cities, such as Siping and Liaoyuan, are located in the second and third quadrants, and have not yet highlighted their spillover effects.

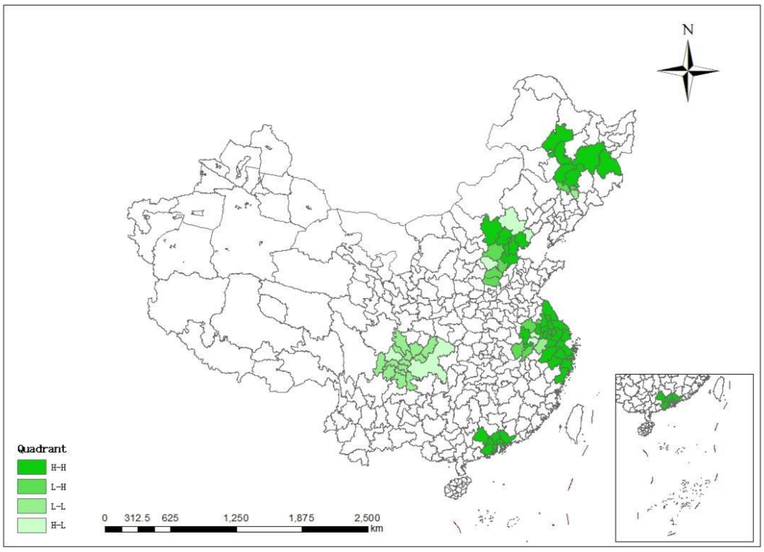


Figure 2. *Spatial Distribution of Moran Index for Selected Urban Agglomerations in 2020.*

5. Conclusions of the Study and Recommendations for Countermeasures

5.1. Conclusions of the Study

(1) Practicing the carbon peaking and carbon neutrality goals helps to improve the level of urban green competitiveness, which is conducive to the creation of ecological civilization cities, proving that the carbon peaking and carbon neutrality issue proposed by the state is the need of economic reality. The empirical regression found that the carbon intensity and urban green competitiveness show a negative relationship, the lower the carbon intensity leads to the higher urban green competitiveness, and after a series of robustness tests found that the results remain stable. Sample regression can be concluded that the impact of carbon emission intensity of large cities on urban green competitiveness is greater than the impact of carbon emission intensity of small cities on urban green competitiveness.

(2) In addition, whether or not there is policy guidance, such as whether or not it is a pilot low-carbon city and whether or not it is an ecological civilization demonstration city or county, has a positive effect on the level of urban green competitiveness; the advanced industrial structure also shows a significant promotion of urban green competitiveness, and the increase in the average wage of employees has a promotional effect on the level of urban green competitiveness.

(3) There is a positive spatial correlation of urban green competitiveness. Through the global spatial autocorrelation analysis, it can be seen that the urban green competitiveness index has a positive agglomeration effect in space, and with the increase of time, the level of urban green competitiveness rises gradually, which indicates that the green development of the city has achieved certain results, and that while focusing on economic development, it has also taken into account the sustainability of the city's environment; through the local spatial autocorrelation analysis, it can be seen that the urban green competitiveness of high agglomeration of cities are mostly economically developed areas in the east, indicating that its economic development has also realized the green development of the city, which produces a certain spatial positive externality, while the urban green competitiveness of the low-low agglomeration indicates that its level of green development is relatively low and the surrounding areas have not formed a certain scale effect, mostly in the western region where the economy is relatively backward.

(4) Some potential cities have undergone quadrant jumps in urban green competitiveness over time. Areas located in high and low agglomeration have gradually shifted to high and high agglomeration areas, and most of these areas are new first-tier or second-tier cities.

5.2. Policy Recommendations

5.2.1. The Government Guides the Differentiation of Cities to Realize Green Development

On the one hand, to plan the green development of the city from the top level design, the government departments improve the relevant laws and regulations on environmental supervision, and increase the supervision of the intensity of carbon emissions in the city, and improve the laws and regulations related to the carbon emission rights of the existing enterprises, so as to internalize the negative externality generated in the process of the development of the enterprises; on the other hand, to create a green business card of the city, and to give the city the green-related honors. For example, the government encourages cities to carry out green transformation by setting up low-carbon pilot cities and other policies. In addition, differentiated policies are set up for different types of cities, such as encouraging resource-based cities to accelerate industrial transformation, and encouraging innovative cities to develop their industrial structure in an advanced way, and implementing certain honorary rewards for them respectively. For small cities, their economic development is still in the early stage, environmental problems are relatively simple and easy to manage, green development to enhance the role of the more significant, and encourage their economic development while focusing on the enhancement of urban green competitiveness, the traditional development model at the expense of the environment does not work, and accelerate the innovation of the urban development model in order to realize the sustainability of the urban development model.

5.2.2. Guide the Advanced Development of Urban Industrial Structure

To reasonably upgrade the urban industrial structure. For high energy-consuming and high-polluting industries, we should implement certain policies or institutional constraints to force enterprises to carry out low-carbon technological transformation and improve their green technological innovation ability, while providing certain tax incentives or financial subsidies for green enterprises to attract production factors to flow to low energy-consuming and low-polluting industries, and guide the greening and advanced development of urban industrial structure. At the same time, the city realizes differentiated policies for different industries, encourages the city to use local resource endowments to develop characteristic green industries, promotes the advanced and rationalization of urban industries, and turns the green water and green mountains and icebergs and snowy mountains into mountains of gold and silver.

5.2.3. Raise Residents' Awareness of Green Consumption

Urban green competitiveness not only needs to play a role in the supply side, but more importantly, the demand side where the consumer is located, to realize the whole process of green consumption from the source, to improve the public's awareness of environmental protection, and to reduce the demand for polluting products, the residents with higher incomes will put forward higher requirements for the development of the city, for example, in addition to the development of the city about the economic aspects of the city, more about the quality of life in the city, such as urban environmental protection and so on, so that Therefore, it is necessary to appropriately increase the income of residents to encourage their awareness of environmental protection, which will help to improve the level of green competitiveness of the city from the demand side.

5.2.4. Planning Green Development Demonstration Cities

Actively create growth poles of green competitiveness in large cities and drive the improvement of green competitiveness in surrounding cities, making full use of the spatial spillover effect of urban green competitiveness. Create a positive demonstration effect between cities, promote green development exchanges between neighboring cities, complement each other's strengths and shortcomings in competition, cooperate with each other, and jointly promote the improvement of the level of urban green competitiveness, and actively play a positive spillover effect of districts and counties with high levels of green competitiveness within the city. For the cities with high urban green competitiveness level, guide them to help the green development of the neighboring cities, and turn the cases of green competitiveness development of their own cities into promotable experiences for the reference of the neighboring cities, regarding the transfer of polluting industries to the neighboring cities is an unsustainable development, and it is difficult to realize the development of inter-regional green level, therefore, each city has to find the green transformation road that suits its own actual situation, so as to achieve a higher level of urban green competitiveness. At the same time, for the cities in the fourth quadrant of high-low agglomeration, actively promote the green development of cities with development potential, in its own development at the same time, release the spillover effect, drive the development of green competitiveness of neighboring cities, and promote the coordinated development of the region, so as far as possible to realize the transition from the second, third, and fourth quadrant to the first quadrant.

Abbreviations

UGC: Urban Green Competitiveness
CI: Carbon Emission Intensity
GC: Green Cities
IS: Industrial Structure
Fin: Financial Self-Sufficiency
FDI: Foreign Direct Investment
Moran's I: Moran Index

Conflicts of Interest

The authors declare no conflicts of interest.

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