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Empirical Study on the Impact of Urbanization and Carbon Emissions under the Dual-Carbon Framework Based on Coupling and Coordination

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Abstract: At present, there are two modes between urbanization and carbon emissions, namely mechanisms of increasing carbon and mechanisms of decreasing carbon. This paper uses the definition of environmental coupling and coordination to study the effect of the mechanism of reducing carbon emissions in urban construction and empirically analyzes its relationship with carbon emissions under the background of dual-carbon. In addition, through the selection of the relevant index system and the objective design of the parameters in the model of the traditional coupling coordination degree, the temporal and spatial characteristics of the relationship between the two are analyzed. The coupling coordination degree of urbanization construction and the improvement of carbon emission systems in all provinces is generally on the rise. This is specifically reflected in the range of the coupling coordination degree in 2020 (0.1621~0.7334), which is first enhanced and then weakened compared with the previous data (0.1282~0.4868), indicating that the positive promotion effect of regional urban development and cooperation regarding the construction of low-carbon environments is declining. The maximum value of regional spatial autocorrelation reached 0.24, and the regulatory interaction coefficients of carbon reduction technology and regional cooperation were 0.1538 and 0.4807, respectively. This indicated a positive role in promoting the development of regional urbanization, which can accelerate the process of carbon reduction. However, at present, the positive effect of urbanization construction cooperation or carbon emission reduction cooperation is weakening, and the characteristics of spatial imbalance are relatively obvious. Therefore, in the future, administrators should speed up the adjustment of the spatial coordination of urban development and the formulation of relevant carbon emission reduction policies and measures and improve the spatial relevance of the coupling coordination degree so as to achieve the efficient development of a low-carbon economy in the context of dual-carbon.

Keywords: coupling coordination degree; urbanization construction; carbon emissions; dual-carbon background; empirical analysis; temporal and spatial evolution characteristics

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1. Introduction

Low-carbon urbanization is inevitable as a response to global climate change, and it is also an inevitable requirement for sustainable development. Urbanization will significantly increase carbon emissions, and it shows a dynamic trend in a certain period of time. Countries with higher levels of urbanization and lower levels of industrialization have more carbon emissions [1,2]. Strengthening the low carbon development trend of cities is in line with the sustainable development strategic goals and can effectively alleviate the contradiction between urbanization and carbon emission control. Urbanization development and carbon emission systems are relatively complex and are affected by many subjective and objective factors. Most scholars have explored the path of the development of urbanization under sustainable development. For example, Tan et al. used panel data to explore the impact of foreign investments on carbon neutrality under globalization and analyzed this from the threshold of urbanization and the intermediary effect. The results found that the rationalization of the industrial structure and the improvement of the technical level can ensure the coordination of regional development [3,4]. Guo et al. proposed that attention should be paid to carbon emissions in the construction field, and the level of energy conservation should be improved through the selection of building materials and the formulation of related emission reduction measures so as to reach the carbon peak as soon as possible [5]. Zhao et al. also recognized the importance of tourism urbanization in a low-carbon economy, analyzed the urbanization level of tourism-oriented cities based on case studies, and helped them actively formulate relevant planning programs to achieve sustainable development [6]. Liu et al. posited that there is a certain coupling of and interaction between urbanization and the ecological environment, and the results of their experimental model also showed that reasonable adjustments to the industrial structure can keep the scale of the ecological footprint stable [7].

Much divergence exists in REDD horizontal under different urbanization modes. When it is difficult to achieve a coordinated development state between the urbanization development process and carbon emissions, it will cause higher carbon emissions, which in turn will restrict the speed and quality of economic development [8]. Zhou et al. used the VAR model and pulse analysis to analyze the relevance between urban land construction and carbon emissions. The results showed that construction land had a greater impact on carbon emissions in the early stages of development, but with the improvement of infrastructure, other negative effects gradually decreased and entered a stable state [9]. Gong et al. analyzed the coupling development of a low-carbon economy and enterprises with the help of a neural network and found that enterprises should actively undertake social responsibilities, reduce the use of fossil fuels, and contribute their own strengths to the low-carbon circular economy [10]. Song and his research team built a coordination system model with a coupling model and analyzed the overall urban economic development and carbon emissions. The research shows that the size of per capita carbon emissions make a large difference in regional coupling [11,12]. Chen et al. explored the relationship between carbon emissions and the ecological environment and found that the dynamic balance between the two needs to be more coordinated under the support and guidance of the government [13]. Shi et al. constructed an index system for accelerating the low-carbon growth of Chinese cities, and the results showed that reducing carbon emissions in the construction and transportation sectors can effectively contribute to the coordinated development of cities [14]. Yu et al. analyzed the spatial coordination of Chinese cities and found that there are differences in the scale of the expansion of urbanization in cities. Furthermore, they found that the overall efficiency of resources is not optimal, and the scale of the city can affect the degree of regional coordination to a certain extent [15].

Rapid urbanization has destroyed the structure and function of the ecosystem, and the deterioration of the ecological environment has also hindered the quality of urban development and restricted the sustainable development of cities. In order to deeply explore the coordination measurement and spatio-temporal heterogeneity between urbanization and ecological environment, Ma et al. took the statistical data of Shaanxi Province from 2005 to 2019 as an example and explored the dynamic change and spatio-temporal heterogeneity of the coupling relationship between regional urbanization and the ecological environment with the help of the construction of an indicator system, coupling coordination degree model (CCDM), relative development degree model (RDDM), and geographic and time-weighted regression (GTWR). The results show that the growth rate of the ecological environment in Shaanxi Province is lower than the urbanization level, and the spatial difference of the coupling and coordinated development state between different regions is significant, which is generally recognized as "lagging urbanization—synchronous development—lagging ecological environment" [16]. Zou et al. asserted that the mixing of urban functions under the blind expansion of urban space seriously restricts the level of urbanization development, so it is very important to strengthen the analysis of the degree of coordination between the two. Their model of information entropy and time entropy was constructed with the help of urban interest points and track data. The results show that the higher the degree of spatial agglomeration, the higher the degree of urban function mixing and urbanization development, and the higher the degree of coupling and coordination between urbanization development level, POI spatial entropy, and taxi time entropy. Therefore, the degree of coupling coordination is of great significance and value in the rational planning of the construction of urban functional areas and the sustainable development of cities [17]. In the context of rapid development, the problems of urbanization construction, resource consumption, and ecological environment are increasingly prominent. A comprehensive study of urbanization level (CUL) and ecological total factor energy efficiency (ETFEE) is conducive to the development of new urbanization and ecological protection. Xia et al. built a multi-dimensional urban evaluation system and calculated it with the coupling coordination degree (CCD) model. The results show that CCD is transiting from a low-to-medium coupling stage to a medium-to-high coupling stage [18]. Chen et al. applied AHP, grey correlation analysis, and coupling theory to evaluate the dynamic characteristics and influencing factors of ecological civilization, and the results showed that the comprehensive coupling coordination significantly improved the degree of institutionalization in 2006–2017. Additionally, the results showed that the ecological environment was still the main constraint subsystem affecting ecological civilization [19]. Li et al. took Wuhan, a megacity in China, as an example to analyze the balance between urban construction and resources and the environment with the help of an index system, bivariate autocorrelation model, coupling coordination model, and spatial lag model (SLM). The results show that the social economy and the construction of regional relations have an obvious overall positive correlation, with a high degree of agglomeration and strong spatial heterogeneity. The spatial agglomeration effect can improve the urban development capacity and the level of resources and the environment [20].

Under the accelerated development of urbanization, the content of carbon dioxide in the air is on the rise, and the resulting climate change also greatly restricts the level and quality of urbanization development. The problems between economic development, resource consumption and the ecological environment are increasingly prominent and to a certain extent, restrict the long-term benign development relationship. Urbanization is an important force in promoting China’s economic and social development and also one of the main reasons for the sustained growth of China’s energy consumption and carbon emissions. The research on the relationship between urbanization and carbon emissions can not only provide a reference for China to achieve the goal of carbon peak and carbon neutrality but also provide certain theoretical support for China’s urban planning and construction. By analyzing the relationship between urbanization development and carbon emissions in China and studying the relationship between urbanization construction and carbon emissions, the coordinated development of urbanization construction and carbon emissions can be promoted. At the same time, it is very important to pay attention to how the social economy and social culture interact to promote each other, develop together, and form a virtuous circle and interactive relationship in the process of urbanization. The coupling coordination degree is more important in urbanization construction, especially under coupling coordination development. As an assessment of the coordination relationship of different system elements in the development stage, the coupling coordination degree can effectively reflect the overall situation under the characteristics of the urban development stage, further helping the government decision-makers to realize the adjustment of relevant policies according to the actual development situation and better maintain a harmonious symbiotic relationship with the resources and environment. As an important indicator of the level of national and regional economic and social development, cities, as an organism, contain many resources and contents. Urbanization construction and development can greatly improve the quality of regional development, but at the same time, it may also bring some environmental problems, such as the wasting of energy and resources, ecological environment damage, etc., which is not conducive to the sustainable development of the environment. The relationship between human activities and the natural environment does not exist in isolation but affects and restricts each other. At the same time, in the past, most researchers used the coupling co-scheduling model and variable regression model to conduct empirical analysis when analyzing the level of urbanization construction and environmental resources. They proved that ensuring the good development of urbanization construction can maintain a long-term and effective symbiotic relationship with environmental conditions. Therefore, introducing the coupling coordination degree into the empirical study on the relationship between urbanization construction and carbon emissions can effectively reduce the damage of urbanization to the environment and resources during the construction process, and with the help of the analysis of the dual-carbon target, it can effectively promote the development of low-carbon urbanization and improve the environmental quality, which is important to ensure the quality of human life.

In view of the contradictions and constraints between the current urbanization construction and the carbon emission environmental situation, the study proposes to promote low-carbon urbanization construction under the guidance of coupling and coordination scheduling. The concept of coupling coordination degree in the ecological sense is transferred to the development relationship of low-carbon cities and towns, and the relationship between urbanization and carbon emissions is empirically analyzed under the framework of a dual-carbon background. The first task to promote the construction of low-carbon urbanization is to correctly understand the coupling relationship between the two systems, which includes two connotations. It is thus necessary to have a deep understanding of the coupling law of urbanization construction system and carbon emission system. The second is to accurately grasp the current situation of the coupling between urbanization construction and the carbon emission system, including the current stage and factors restricting development. Based on this, the study first analyzes the systematic correlation between urbanization construction and carbon emissions, then constructs an indicator system of the relationship based on the coupling coordination degree. Then, a regression analysis model and intermediary effect mechanism are designed for urbanization construction and carbon emissions. In the result analysis part, the effectiveness of the coupling coordination degree model, the spatiotemporal characteristics of urbanization and carbon emissions, and the intermediary effect and regression results of the model are discussed. The experimental results are discussed, and the relevant data are compared and analyzed in the discussion part in order to provide decision-making guidance and suggestions for the development of low-carbon urbanization. That is, by means of analyzing the evolution of the coupling relationship between urbanization construction and carbon emissions, the research goal is to provide a reference for the design of a low-carbon urbanization construction policy system.

2. Research on the Relationship Mechanism between Urbanization and Carbon Emissions under the Dual-Carbon Framework Based on Coupling and Coordination

2.1. The Relevance and Systemicity of Urbanization Construction and Carbon Emissions

Sustainable development requirements aim to satisfy the demand of contemporary people without causing harm to future generations. It pursues a longer-term and orderly development prospect in the time dimension, which is a balanced and coordinated form of progress that ensures the quality and speed of development [21,22]. The current urbanization construction road will inevitably face problems such as unbalanced resource consumption, environmental pollution, and unreasonable industrial structure at different development stages, which will lead to a low degree of sustainable development of the urbanization road. As an important indicator for assessing environmental quality, whether the carbon emissions are reasonable will impact economic development to varying degrees [23,24]. Urbanization construction and carbon emission systems are both subsystems in the economic system, but they can also constitute a composite system that restricts and influences each other. While ensuring the improvement of urbanization, the formulation and implementation of relevant carbon reduction policies can effectively ensure the long-term sound development of the economic state and the coordinated and sustainable development of the environment [25,26]. As an important material basis for urbanization, carbon resources are an important source for maintaining human production and life. Carbon resources can provide materials for urbanization through mining and processing. Population, as an important subject in the development of urbanization and an important carrier of carbon dioxide conversion, not only undertakes the regulating role between urbanization construction and carbon emission systems but also plays an important role as an intermediary variable. When excessive carbon emissions threaten and damage the living environment of the human body, people will have low-carbon environmental protection awareness, accelerate the research and development of low-carbon technologies, and use artificial means to consciously reduce carbon emissions to promote the orderly and steady level of urbanization [27,28]. At the same time, this relationship is an interconnection between the urbanization construction system and the carbon emission system. When this relationship is positive, it can accelerate the growth of low-carbon cities. When it is a restrictive relationship, it will promote the development of cities with high carbon. Strengthening the regulation of subsystems in the system can effectively make the city develop benignly [29,30].

In Figure 1, the development of urbanization drives the consumption of related carbon-containing energy. If the excessive carbon emission pressure is not relieved, it will cause environmental and ecological changes and pose a threat to human survival and development. Therefore, people will consciously intervene to reduce carbon emissions so as to reduce the negative effects of urbanization.

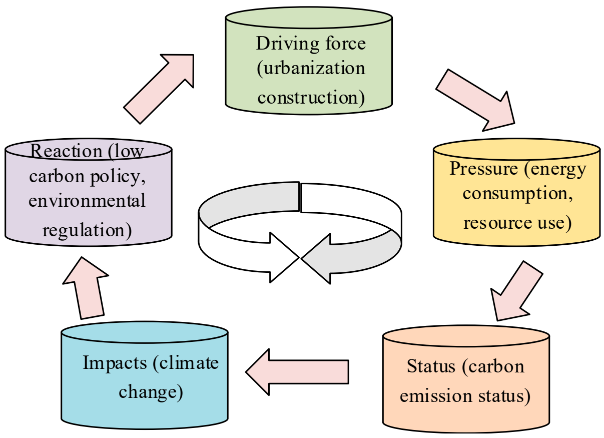


Figure 1. Relationship between urbanization level and carbon emissions.

2.2. Urbanization Construction and Carbon Emission Analysis under Coupling Coordination Degree

The coordination degree is often used to evaluate the internal relationship between elements and the overall interaction degree of the system.

$$C = \left\{U(V) * U(W)/([U(V) * U(W)]/2)^2\right\}^{0.5} \tag{1}$$

In Formula (1), C is the degree of coupling, and $U(V)$ and $U(W)$ are the state level of urbanization and carbon emissions under the systemic construction goals. When the coupling degree is 0 or 1, it shows the maximum and minimum values of correlation. When the system levels of the two are equal, the coordination is the highest, but the actual level of the urbanization system and the carbon emission system does not represent the optimal value, so the coupling degree model struggles to correctly evaluate the state of the urban low-carbon economy [31]. The degree of coupling coordination is often used as a measure of correlation, which can effectively report the level of interoperability between systems and the performance level of the system itself. It can effectively conduct an empirical analysis of the developing relationship of regional elements [32]. Its mathematical expression is Formula (2).

$$D = \sqrt{C * \alpha * U(V) + \beta * U(W)} \tag{2}$$

In Formula (2), D is the degree of coupling coordination, C is the multipurpose contribution degree of urbanization construction and the carbon emission system, and α, β are the corresponding weight values of the two systems. The hierarchical performance of the system evolution dynamics requires the system to maintain a good coupling level and make the direction of development more consistent. As an important evaluation index of the system's level, the coupling degree is proportional to the system level [33]. For the sake of better assessing the coupling coordination relationship between urbanization construction and carbon emission systems, it is graded based on the development levels under different coordination degrees. The levels are divided into imbalanced development, transitional development, and coordinated development. Table 1 shows the different degrees of coupling.

Table 1. Classification of coupling scheduling.

Degree of Coordination	Coordination	System Relationship	Degree of Coordination	Coordination	System Relationship
Extreme maladjustment	0~0.09	Low-level symbiosis (weak system connection)	Grudging coordination	0.50~0.59	Maximum development stage (strong interaction between systems)
Severe maladjustment	0.10~0.19		Primary coordination	0.60~0.69	
Moderate maladjustment	0.20~0.29		Intermediate coordination	0.70~0.79	Highly symbiotic stage (coordinated development relationship between systems)
Mild maladjustment	0.30~0.39	Running in development (strengthening system connectivity)	Good coordination	0.80~0.89	
On the verge of maladjustment	0.40~0.49		High-quality coordination	0.90~1.00	

When the coupling coordination value exceeds 0.5, the interaction between urbanization construction and the carbon emission system is enhanced. Under this condition, special note should be made that the increase in carbon emission consumption will be artificially reduced by means of technological innovation and the formulation of relevant carbon reduction policies. When the coefficient outweighs 0.7, it indicates that coordination has been promoted, the operation effect of low-carbon urbanization is obvious, and the overall economic situation is good.

3. Design of Empirical Model of Urbanization Construction and Carbon Emissions Based on Coupling Coordination Degree

3.1. Urbanization Construction and Carbon Emission Level Indicator System

There are differences and dynamic changes in the development of coupling coordination levels in the temporal and spatial dimensions. Accelerating the development of low-level systems and restricting the development of high-level systems can reduce the development gap between systems. The dynamic development characteristics in the temporal dimension mean that the design of its weight value should also be in a state of change and development [34,35]. A high carbon emission level is not equal to the carbon reduction effect brought by it. Therefore, the study believes that construction should focus on the growth of a low-carbon economy as much as possible so as to promote the sustainable development of urban construction. Considering that the subjective setting of the weight value in the traditional coupling coordination degree model will affect the objectiveness of system importance, it is difficult to correctly evaluate the state of the level of harmonizing between two systems [36]. Therefore, the research objectively defines the weight value here; that is, it assigns a larger weight value to the low-level system to ensure the coordination between the two systems and fully considers the time variability of the weight value. The setting condition formula is shown in Formula (3).

$$\begin{cases} \alpha > \beta, when\ U(V) < U(W) \\ \alpha < \beta, when\ U(V) > U(W) \\ \alpha + \beta = 1 \end{cases} \tag{3}$$

After processing the parameters, a new co-scheduling model can be obtained, as shown in Formula (4).

$$D* = \sqrt{C * \alpha' * U(V) + \beta' * U(W)} \tag{4}$$

In Formula (4), α', β' are the system parameters obtained by reprocessing. The study conducts a correlation analysis between urbanization and carbon emissions and defines a scalable stochastic environmental impact assessment model (STIRPAT), as shown in Formula (5).

$$In(I_{it}) = \alpha + \beta In(P_{it}) + \mu In(A_{it}) + \delta In(T_{it}) + \varepsilon_{it} \tag{5}$$

In Formula (5), I is the carbon emissions, P, A, T are the population index, economic affluence, technical index and energy intensity, respectively, t is the year, β, μ, δ are coefficients, α, i express the period effect and individual effect, respectively, and ε is the error term. The constructed model was tested by panel data and analyzed by the covariance F effect test and Hausman test. In the process of construction, the degree of urbanization is simply defined by the increase in urban population and gradually transformed into a process measurement index covering population, economic, spatial, and social. This can avoid the limitations of static and single evaluation indicators [37,38]. Carbon emissions are mainly the release of carbon dioxide as the main greenhouse gas, and its main source is energy consumption. Energy consumption intensity and consumption methods will have varying degrees of influence on carbon emissions. With the continuous development of urbanization and the decline of relevant policy constraints, carbon emissions are showing an upward trend. Excessive carbon emissions will not only cause irreversible damage to the environment but also have a certain restrictive effect on the quality and speed of urbanization and economic improvement [39]. The present study firstly constructs a system of urbanization construction level indicators and carbon emission-related indicators (in Table 2).

Table 2. Urbanization construction level and carbon emission indicator system.

System	Index		Number	Attribute
	Level I Indicators	Secondary Indicators		
Urbanization construction	Population (P)	Urban population	P1	+
		Proportion of non-industrial and agricultural employees (%)	P2	+
	Economy (E)	Per capita financial income (yuan)	E1	+
		Total fixed investment per capital (yuan)	E2	+
		Proportion of economic growth in the tertiary industry (%)	E3	+
		Per capita gross industrial output value (yuan)	E4	+
		Per capita consumption and sales volume (yuan)	E5	+
	Space (S)	Per capita living area in cities and towns (m^2)	S1	+
		Per capita built-up area (m^2/person)	S2	+
		Urban population density (person square kilometers)	S3	+
		Proportion of land area of built-up area in total urban area (%)	S4	+
	Social (C)	Number of public transport (10^2 persons/vehicle)	C1	+
		Per capita urban road area (m^2)	C2	+

Table 2. *Cont.*

System	Index		Number	Attribute
	Level I Indicators	Secondary Indicators		
Carbon emission system	Energy consumption	Proportion of coal consumption (%)	T1	-
		Proportion of natural gas consumption (%)	T2	-
		Proportion of oil consumption (%)	T3	-
		Proportion of non-fossil energy in disposable energy (%)	T4	-
	Energy consumption per unit GDP (10,000 tons/100 million)		u	-
	Total energy consumption per capita (ton)		M1	-
	Energy consumption per capita (kg coal equivalent)		M2	-
	Per capita consumption of carbon emissions (tons of standard coal/person)		M3	-
	Carbon emissions under industrial value-added		M4	-
	Comprehensive utilization amount of waste		I1	+

Note: "+" and "-" in the table represent positive and negative indicators and their active and passsive influence on the raise of the system horizontal.

At the same time, the entropy weight method is used to set the weight value to reduce the influence of objective error; that is, to realize the objective evaluation of the index through normalization processing, index weight value setting, and information entropy setting. Its mathematical expression is shown in Formula (6).

$$\begin{cases} r_{ij} = \frac{(X_{ij} - \min(X_j))}{(\max(X_j) - \min(X_j))} \\ P_{ij} = \frac{r_{ij}}{\sum\limits_{i=1}^{n} r_{ij}} \end{cases} \quad (6)$$

In Formula (6), X, i, j are the province, year and indicator, respectively, $\max(X_j)$, $min(X_j)$ are the two extreme values of the corresponding indicator, r_{ij} is the normalized result, and P_{ij} is the weight value.

$$W = \frac{1 - (-\frac{1}{In\ n}\sum\limits_{i=1}^{n} P_{ij} * In\ P_{ij})}{\sum\limits_{i=1}^{m}\left[1 - (-\frac{1}{In\ n}\sum\limits_{i=1}^{n} P_{ij} * In\ P_{ij})\right]} \quad (7)$$

In Formula (7), W is the weight value, $\left(-\frac{1}{In\ n}\sum\limits_{i=1}^{n} P_{ij} * In\ P_{ij}\right)$ is the information entropy, and m is the number of years. Then the urbanization system level and carbon emission level can be obtained through the weight value, as shown in Formula (8).

$$\begin{cases} U(V)_i = \sum\limits_{j=1}^{nv} W^v{}_j * rv_{ij} \\ U(W)_i = \sum\limits_{j=1}^{nw} W^w{}_j * rw_{ij} \end{cases} \quad (8)$$

In Formula (8), n_v, n_w are numbers of indicators evaluating the sum of system status levels.

3.2. Intermediary Effect of Urbanization Construction and Carbon Emission Levels and Design of Regression Analysis Model

Adjusting the level of urbanization can effectively interfere with carbon emissions. Giving impetus to the new urbanization process is not only a further improvement in the level of urbanization but, more importantly, an improvement in the connotation goals and the pattern of spatial development. This promotion pays more attention to the intensification and high utilization of energy [40]. As significant behavior to push forward the growth of urbanization, environmental regulations have a positive “reverse effect” on carbon emissions; that is, by adjusting tax policies and strengthening support for innovative energy-saving technology and equipment, energy efficiency can be pushed forward, and carbon emissions can be lessened. However, environmental regulations will produce a negative “regression effect” under stricter conditions. Strengthening the spillover effect of external infrastructure construction and improving energy efficiency can effectively reduce carbon emissions. The study considers that there is a certain time lag in carbon emissions, and its effect is less sensitive to time changes [41]. Therefore, the regression analysis is carried out with the help of the GMM model, as shown in Formula (9).

$$\begin{aligned} Y_{it} &= c_1 Y_{i,t-1} + c_2 Y_{i,t-2} + c^{DID} + \sum \alpha_i control_{it} + u_i + v_i + \varepsilon_{it} \\ M_{it} &= a^{DID} + \sum \beta_i control_{it} + u_i + v_i + \varepsilon_{it} \end{aligned} \quad (9)$$

In Equation (9), Y represents per capita carbon emissions, $Y_{i,t-1}, Y_{i,t-2}$ represent the first-order and second-order lag items, respectively, and M_{it} is an intermediary variable, which includes environmental regulation, infrastructure construction, and energy efficiency. $control_{it}$ is a control variable, in which DID is a double-difference model. Furthermore, u_i is a personal fixed effect, and ε_{it} is the disturbance term [42]. The GMM method is the first method used for dynamic model analysis. It is based on two assumptions. First, there are two random error terms; that is, the relationship between the error terms is linear. Second, the observability assumption is that there is only one observation value. The GMM method is based on the above two assumptions. In the regression analysis, every equation in the GMM model is linear, and the coefficient in the equation is constant or at its minimum value. There is a random error term, and the data must be observable. The model does not need to re-estimate the model parameters when introducing new variables, and it can easily carry out regression tests and predictions after estimating the model parameters, with a good regression effect. At the same time, considering that the effect model will be changed by the influence of the adjustment factor when the variable is input, the adjustment variable is added to the mediation effect model, and it is corrected to improve the applicability and interpretability of the model. The mathematical expression is seen in Formula (10).

$$\begin{aligned} Y_{it} &= c_1 Y_{i,t-1} + c_2 Y_{i,t-2} + c^{DID} * U_{it} + \sum \alpha_i control_{it} + u_i + v_i + \varepsilon_{it} \\ M_{it} &= a_0 + a_1{}^{DID} + a_2 U_{it} + a_3{}^{DID} * U_{it} + \sum \beta_i control_{it} + u_i + v_i + \varepsilon_{it} \end{aligned} \quad (10)$$

In Formula (10), U is the moderating variable, and M is the intermediary variable. Then, to better assay the spatial effect connection between urbanization and carbon emissions, the present study uses a spatial correlation model for analysis and testing. Spatial autocorrelation aims to judge the similarity between the sample index attribute value and the spatial value. The positive or negative of the value is proportional to the consistency of the spatial change effect; that is, the positive correlation coefficient indicates that the research sample and its neighboring samples have the same spatial variability. Among them, the Moran index is a significant norm for estimating spatial correlation; the value range of its numerical results is between ± 1, and the closer the value is to the extreme value, the stronger the correlation is. The research uses the Moran index to analyze the spatial distribution of the coupling coordination degree, that is, assay the difference and change the characteristics of the coordination degree in local space and overall space [42]. The formula of the global correlation is shown in Equation (11).

$$\begin{cases} I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} (x_i - \overline{x})(x_j - \overline{x})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}} \\ S^2 = \frac{1}{n} \sum\limits_{i=1}^{n} (x_i - \overline{x})^2 \end{cases} \quad (11)$$

In Formula (11), i, j represent the spatial units, and n is the quantum of the room unit element. x_i, x_j are the carbon emission values corresponding to the spatial unit. S^2 is the sample variance, and $\overline{x}$ is the average value of the observation sample. The spatial correlation is usually analyzed with the help of statistical tests. When the global correlation and the positive value are larger, the urbanization construction can effectively promote the urbanization development of adjacent areas or carry out inter-regional carbon reduction cooperation. If the correlation is a negative value, it states clearly that the growth level of inter-regional urbanization is limited, or carbon emissions are transferred into space. Among them, the local autocorrelation performance can better describe the spatial relationship between the sample point and its neighboring points, and the judgment of the local spatial aggregation effect and its changing trend can make the spatial distribution clearer. According to the aggregation value of the local spatial effect, it can be divided into high-high aggregation areas (high-high, HH), high-low aggregation areas (high-low, HL), low-high aggregation areas (low-high, LH), low-low aggregation areas (low-low, LL), and insignificant areas (not significant) [43]. Its mathematical expression is shown in Formula (12).

$$I_i = \frac{(x_i - \overline{x})}{S^2} \sum_{i=1,j=1}^{n} W_{ij}(x_i - \overline{x}) \quad (12)$$

In Formula (12), W_{ij} is the weight matrix of the regional spatial relationship. The space matrix can be expressed as the adjacency relationship and the distance relationship, which, respectively, represent the local correlation and the long-distance correlation. The connection between regions makes variables have spatial spillover effects. The research uses the space Markov chain to analyze the adverse effects of adjacent regions, as shown in Formula (13).

$$Laga = \sum Y_b W_{ab} \quad (13)$$

In Formula (13), a, b are the regions, Y_b is the carbon emission per capita, and W_{ab} is the spatial relationship between regions. As a quantitative method, the spatial Markov chain has unique advantages in dealing with spatial autocorrelation and spatial spillover effects. The spatial Markov chain model is used to explore the anti-impact effect. It is assumed that the variables in one region in the model also have the same status in another region, but there is a non-negligible relationship between them. Therefore, if the variable (or its state) of one region changes (for example, from equilibrium to unbalanced), it will have an impact on the neighboring region. With the help of the spatial Markov chain, the spatial relationship between regions can be analyzed, and the spatial characteristics of variable factors can be excavated. Then, the impact factors of urban urbanization and the internal mechanism of carbon emissions can be analyzed.

4. Validity Test and Empirical Relationship Research of Coupling Coordination Degree Model

4.1. Analysis of Coupling Coordination Degree Model

The study selected the face-plate of 30 provinces and cities in China to analyze the validity of the model. The index data came from the *China Statistical Yearbook* (1998~2020) and the statistical yearbooks of those regions, and the index weight values of the two systems were obtained, as shown in Table 3.

In Table 3, the proportion of the urban population, per capita fiscal income, and urban population density are the key norms that affect urbanization, and their weights account for 59.16%, 12.47%, and 10.89%, respectively. Analyzing the indicators that affect the degree of the carbon emission system, it is obvious that per capita carbon emissions play a major negative role, with a weight value of 14.26% and a weight of 14.23% for waste management indicators, which have good positive attributes. At the same time, energy consumption will also generate more carbon emissions. Hu et al. studied the spatial correlation of building carbon emissions and its influencing factors and analyzed the network structure with the help of a social network analysis method. The results show that geographical proximity, economic development level, energy intensity, and industrial structure are significantly related to building carbon emissions. Moreover, the spatial correlation and stability of Shanghai, Jiangsu, Tianjin, Beijing and Zhejiang are gradually increasing. The formulation of energy-saving policies can effectively promote cross-regional cooperation and emission reduction [43]. The above results show that there are many factors affecting the development of low-carbon cities, and they show certain spatial heterogeneity. Then, we can calculate the coupling coordination degree of Chinese provinces and cities, as shown in Table 4.

Table 3. Evaluation index system and weight value of urbanization carbon emission system coordination.

System	Evaluating Indicator		Unit	Weight Value	Indicator Attribute
	Level I Indicators	Secondary Indicators			
Urbanization construction	Urban population	Proportion of urban population	%	0.5916	+
		Number of urban non-agricultural employed population	Ten thousand people	0.0852	+
	Economic level	Per capita financial income	yuan	0.1247	+
		Investment in fixed assets	yuan	0.0964	+
		Economic proportion of secondary and tertiary industries	%	0.0577	+
	Infrastructure	Urban living area	Square meter	0.0711	+
		Per capita road area	Square meter	0.0569	+
		Built up area	M^2/person	0.0784	+
	Urban population density		Person/km^2	Person/km^2	+
	Per capita disposable income		yuan	element	+
Carbon emission system	Proportion of energy consumption	Coal/total energy	%	0.1005	-
		Natural gas/total energy	%	0.2531	-
		Oil/total energy	%	0.0523	-
	Per capita living energy consumption		ton	0.0489	-
	Carbon emissions per capita		Tons of coal/person	0.1426	-
	Industrial value-added carbon emissions		10,000 tons of coal/100 million	0.0345	-
	Unit economic energy consumption		10,000 tons/ 100 million	0.0421	-
	Comprehensive treatment amount of waste treatment		10,000 tons	0.1423	+

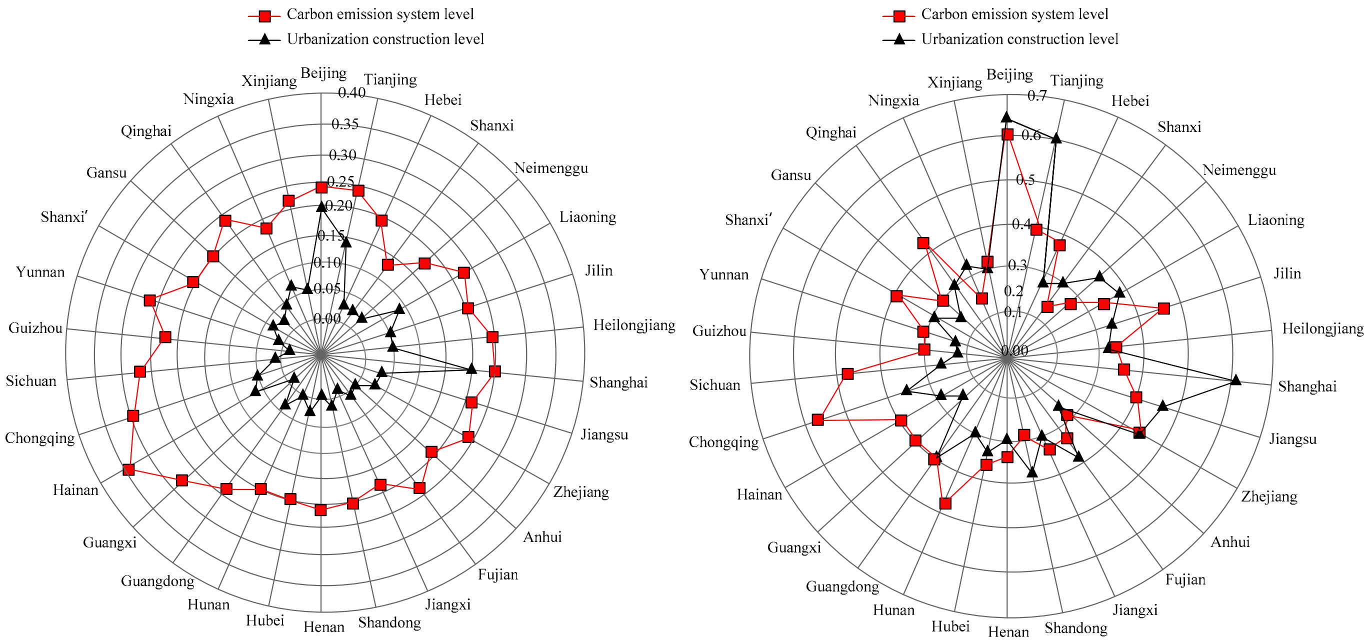
Table 4. Coupling and coordination of provincial and municipal urbanization construction and carbon emission systems.

Province	Urbanization Construction		Carbon Emission System		Coupling Degree		Coupling Co-Scheduling	
	1998	2020	1998	2020	1998	2020	1998	2020
Beijing	0.5531	0.5795	0.5619	0.527	0.3328	0.3546	0.4114	0.7334
Tianjin	0.4468	0.4732	0.4340	0.3991	0.2693	0.2911	0.2843	0.6063

Table 4. *Cont.*

Province	Urbanization Construction		Carbon Emission System		Coupling Degree		Coupling Co-Scheduling	
	1998	2020	1998	2020	1998	2020	1998	2020
Hebei	0.3383	0.3644	0.4343	0.3994	0.3273	0.3491	0.3252	0.6472
Liaoning	0.3948	0.4212	0.4655	0.4306	0.3275	0.3493	0.3437	0.6657
Shanghai	0.5438	0.5702	0.4615	0.4266	0.3309	0.3527	0.3895	0.7115
Jiangsu	0.6579	0.6843	0.4413	0.4064	0.3321	0.3518	0.4342	0.7562
Zhejiang	0.5168	0.5432	0.5795	0.5446	0.3343	0.3561	0.4243	0.7464
Fujian	0.3512	0.3776	0.6139	0.5790	0.3142	0.3358	0.3386	0.6606
Shandong	0.5206	0.547	0.5055	0.4706	0.3342	0.356	0.4221	0.7441
Guangdong	0.6839	0.7103	0.4928	0.4579	0.3245	0.3463	0.4868	0.7588
Hainan	0.1581	0.1845	0.6775	0.6426	0.2060	0.2278	0.2126	0.5346
Shanxi	0.2862	0.3126	0.4336	0.3987	0.3034	0.3252	0.2790	0.6010
Jilin	0.2642	0.2906	0.4827	0.4478	0.2866	0.3084	0.2664	0.5884
Heilongjiang	0.3084	0.3348	0.4680	0.4331	0.3096	0.3314	0.2971	0.6190
Anhui	0.3042	0.3306	0.4953	0.4604	0.3266	0.3484	0.3358	0.6578
Jiangxi	0.3047	0.3311	0.5755	0.5406	0.2944	0.3162	0.2972	0.6192
Henan	0.4171	0.4434	0.4309	0.3961	0.3270	0.3488	0.3444	0.6637
Hubei	0.3435	0.3699	0.4862	0.4513	0.3296	0.3514	0.3494	0.6687
Hunan	0.3274	0.3538	0.5010	0.4661	0.3188	0.3406	0.3233	0.6426
Inner Mongolia	0.3045	0.3309	0.4658	0.4309	0.3153	0.3371	0.3063	0.6256
Guangxi	0.2164	0.2428	0.5147	0.5147	0.3120	0.3218	0.2902	0.3241
Chongqing	0.2712	0.2974	0.4698	0.4698	0.3029	0.3247	0.2913	0.3252
Sichuan	0.3301	0.3565	0.4335	0.4689	0.3265	0.3483	0.3326	0.3665
Guizhou	0.1966	0.2230	0.4107	0.4461	0.2816	0.3034	0.2447	0.2786
Yunnan	0.2023	0.2284	0.4963	0.5317	0.3074	0.3292	0.3010	0.3349
Tibet	0.0796	0.106	0.4213	0.4567	0.1262	0.148	0.1282	0.1621
Shanxi	0.3632	0.3896	0.4623	0.4977	0.3219	0.3437	0.3345	0.3684
Gansu	0.2064	0.2328	0.3447	0.3447	0.3003	0.3221	0.2508	0.2847
Qinghai	0.1461	0.1725	0.4087	0.4087	0.2072	0.229	0.1843	0.2179
Ningxia	0.1778	0.2042	0.4175	0.4175	0.1279	0.1497	0.1466	0.1805
Xinjiang	0.2461	0.2725	0.3282	0.3282	0.3141	0.3358	0.2710	0.3049

In Table 4, the urbanization level of each province and city has somewhat improved when comparing 1998 and 2020. In 1998, the highest and lowest urbanization levels were in Beijing and Qinghai, respectively, with a value of 0.5531 and 0.1461. The provinces with the highest and lowest coupling index were Zhejiang Province and the Ningxia Hui Autonomous Region, respectively, with index values of 0.3343 and 0.1279 and corresponding coupling coordination indices of 0.4114 and 0.1497. The average overall coupling degree is 0.2958, which is moderately misaligned at a low level of coupling, and the coupling difference between regions is large. Judging from the data in 2020, the provinces with the highest and lowest coupling coordination index are Guangdong and Tibet, respectively, with values reaching 0.7588 and 0.1621. Moreover, the range of the coupling coordination degree of the urbanization construction and carbon emission system in each province is basically between 0.1621 and 0.7334. The overall coupling coordination level has been significantly improved. This change can be obtained from the historical data in 1998, but the average value is still only 0.5306, which is in the middle stage of development. In addition, these data show a trend of being high in the east and low in the west as regards space, with obvious differences. The content of Figure 2 was obtained by analyzing the provincial and municipal changes in specific conditions. The development of low-carbon cities shows a trend of low energy consumption in economic development. Scholars analyzed the impact transmission mechanism between the pilot policy of low-carbon cities implemented in China in 2012 and urban green total factor productivity (GTFP) with the aid of a DID model. The results showed that the pilot low-carbon cities can effectively achieve intervention through technological innovation, industrial structures, resource allocation, energy intensity, and carbon sequestration. The impact of the policy on large cities, non-resource-based cities and eastern cities is greater than on medium and small resource-based cities and central and western cities [44].



(a) Urbanization level and carbon emission level of provinces and cities in China in 1998

(b) Urbanization level and carbon emission level of provinces and cities in China in 2020

Figure 2. Urbanization construction and carbon emission level of provinces and cities in China in 1998 and 2020. (**a**) Urbanization level and carbon emission level of provinces and cities in China in 1998. (**b**) Urbanization level and carbon emission level of provinces and cities in China in 2020.

Figure 2a,b indicates that the degree of urbanization in all provinces and cities is generally below the degree of the carbon emission system and gradually changes, which exceeds the level of carbon emissions and causes the range of change to increase. Therefore, the increase in the value of the coupling coordination degree in most cities is mostly related to the improvement of the level of urbanization.

4.2. Temporal Change Analysis of Urbanization Construction and Carbon Emissions under the Coordination Degree Model

The degree of interaction between urbanization and the carbon emission system will show large differences in the temporal dimension, and there are two extreme situations of extreme incoordination and extreme coordination. For example, the passive influence caused by the growth of urbanization will make the nature of land use change greatly, thus increasing carbon emissions; alternatively, the development of urbanization can effectively promote carbon reduction and negative carbon emission technologies, reducing carbon emissions to a reasonable range [45]. Table 5 shows the spatial characteristics of coordination relationships among provinces and cities.

Table 5. Value changes of global autocorrelation Moran index from 1998 to 2020.

Particular Year	Moran's I
1998	0.172
1999	0.173
2000	0.175
2001	0.221
2002	0.224

Table 5. *Cont.*

Particular Year	Moran's I
2003	0.238
2004	0.227
2005	0.237
2006	0.177
2007	0.213
2008	0.227
2009	0.210
2010	0.195
2011	0.148
2012	0.131
2013	0.112
2014	0.110
2015	0.085
2016	0.125
2017	0.136
2018	0.177
2019	0.185
2020	0.183

From Table 5, it can be seen that extreme values of the global Moran index before 2005 appeared in 2003 (0.238) and 1998 (0.172), and the overall fluctuation range of the data is less than 20%. However, between 2008 and 2015, the global autocorrelation index declined significantly, and its minimum value reached 0.085, which shows that the spatial correlation trend of the coordination level of urbanization construction and carbon emission coupling between provinces and cities in China is weakening at this time; that is, the positive effects of low-carbon urbanization construction and regional cooperation at this time are decreasing. Although in 2015, the value of the global Moran index picked up and increased, its value was still at a low level. To further assay the local correlation of the spatial aggregation effect, the present study analyzed the spatial distribution of the coupling coordination degree in China in 1998 and 2020 and performed a visual analysis of the Moran index with GIS software. The results are shown in Figure 3.

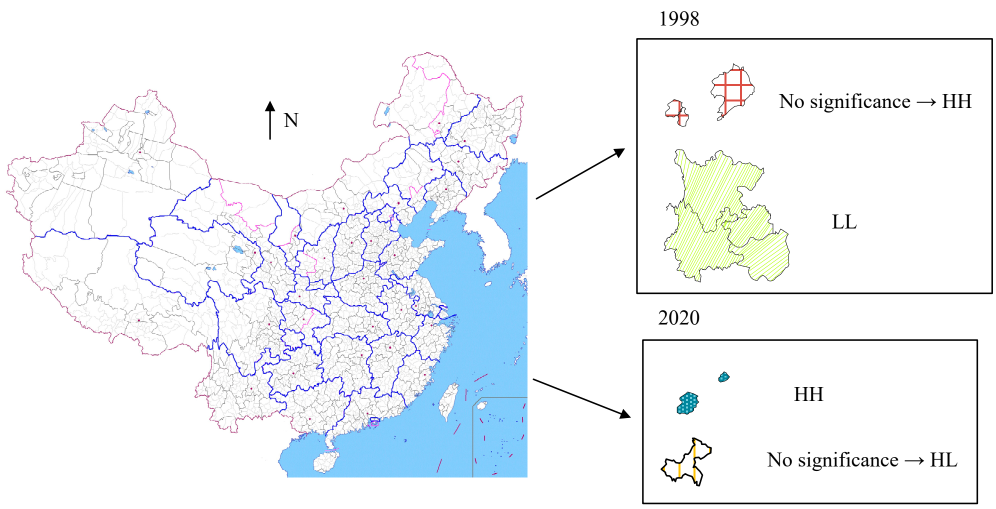


Figure 3. Local Moran Exponential Distribution of Coupling Compatibility.

From Figure 3, it can be seen that, in 1998, high and low values of coupling coordination were mainly concentrated in the Beijing-Tianjin-Ningxia region and the Yunnan-Guizhou-Sichuan region. Compared with the Yunnan-Guizhou-Sichuan region, the Beijing-Tianjin-Ningxia region shows a higher level of urbanization. In 2020, the high-value areas were mainly concentrated in Tianjin and Shanghai, making it clear that while the degree of urbanization is developing well, the effect of low-carbon urbanization is also relatively obvious, resulting in a high level of coupling coordination. This result is consistent with the overall conclusion. Among them, Chongqing City has also changed from an insignificant area to a high-low aggregation area, showing that the value of Chongqing is significantly greater than that of the surrounding areas. The reason is that its overall economic development and carbon emission level are relatively high. From the above analysis, it is obvious that in the initial stage of development, the degree of local coupling coordination is mainly affected by the level of urbanization. The local correlation effect of various provinces and cities in China is weakening, and the impact of urbanization on the degree of coupling coordination is increasing.

4.3. Analysis of Intermediary Regression Results of Urbanization Construction—Carbon Emission System

There are many factors that affect carbon emissions in the course of urbanization. The study selects environmental regulation, infrastructure construction, and energy utilization efficiency to analyze the regional intermediary effect. The research content can be divided into three areas in space. Emissions are the explained variables, mediator variables are the dependent variables, and relevant policy formulation is the core explanatory variable. All dependent variables have passed the control check. Regression analysis and mediation effect Sobel analysis were performed on the experimental results, as shown in Table 6.

Table 6. Regression results of intermediary effects in different regions.

/	Environmental Regulation			Infrastructure			Energy Efficiency		
	East	Central Section	West	East	Central Section	West	East	Central Section	West
DID-E	0.1598 0.79	2.7519 *** 0.00	−1.2977 0.30	0.1598 0.79	−2.7099 *** 0.00	−1.2977 0.30	0.1598 0.79	−2.7099 ** 0.00	1.3397 0.30
R^2	0.4673	0.4337	0.3388	0.4673	0.4337	0.3388	0.4673	0.4337	0.3388
DID-I	0.0243 ** 0.04	0.0589 ** 0.00	0.1045 *** 0.00	0.3007 *** 0.00	−0.0053 0.92	0.0540 0.51	−0.0925 0.13	0.1747 ** 0.01	−0.2081 0.12
R^2	0.3975	2.3535 **	3.0962	0.5248	0.6472	0.6633	0.3715	0.4021	0.4536
M	6.4152 ** 0.00	0.05 −2.5919 ***	0.238 −1.6435	2.2973 ** 0.00	−0.8511 *** 0.00	4.0534 *** 0.00	−0.5028 0.21	−0.6819 *** 0.00	−1.4955 *** 0.00
DID-N	0.3007 0.573	0 0	0.215 0.352	−0 5658 0.291	−2.7354 *** 0	−1.5408 0.220	0.0907 0.869	−2.6115 *** 0	−1.6313 0.201
R^2	0.4935	−0.1376 *	−1.3173	5098.0014	0.4575	0.3952	0.4834	0.456	0.4607
Sobel	0.1618 * 0.07	2.7305 *** 0.05	0.312 0.24	0.7048 *** 0	0.0063 0.9	0.2228 0.49	0.0481 0.32	−0.1195 ** 0.03	0.3115 0.16

Note: "*", "**", and "***" indicate significant differences at the 10%, 5% and 1% levels, respectively.

In Table 6, in the process of urbanization, the policy formulation makes the regression coefficient of the eastern region 0.3007. When the dependent variable is infrastructure, the regression coefficient of the policy is not significant, and the Sobel regression coefficient is 0.7048, indicating that strengthening the construction of infrastructure can effectively intervene in carbon emissions. Under environmental regulations, the regression coefficient in the central region is 2.7519, which is significant, and the regression coefficient in infrastructure construction is 0.0589. When the intermediary variable is energy efficiency, the Sobel test of energy consumption in the central region has a remarkable difference at the 1% level, indicating that strengthening the adjustment of energy structure can effectively intervene in changes in carbon emissions. The Sobel test of the western region under the three intermediary variables is not significant, indicating that it is difficult for this region to effectively intervene in the carbon emission path through environmental regulations, infrastructure construction, and energy efficiency improvements. Meanwhile, a further regression test was developed regarding the impact of environmental regulations (in Table 7).

Table 7. Analysis of the impact of environmental regulations on carbon emissions.

Dependent Variable	Economic Agglomeration		Industrial Structure		Carbon Reduction Technology		Regional Cooperation	
	Coefficient	*p* Value	Coefficient	*p* Value	Coefficient	*p* Value	Coefficient	*p* Value
DID	0.0294 *	0.05	0.0173	0.32	−0.0438 ***	0.01	03867 ***	0.00
ER	0.0922	0.30	0.0557	0.45	0.1538 ***	0.02	0.4807 *	0.06
DID*ER	−0.3627 *	0.00	0.2719 **	0.00	0.1284 **	0.03	−1.4693	0.03
Control variable	Yes	/	Yes	/	Yes	/	Yes	/
C	−2.3432 ***	0.00	−1.2253 *	0.00	0.0671	0.79	7.1957 ***	0.00
R^2	0.4465	/	0.5811	/	0.5231	/	0.1518	/

Note: "*", "**", and "***" indicate significant differences at the 10%, 5% and 1% levels, respectively.

In Table 7, the significance of policy formulation on economic agglomeration is positive, but the outcome of environmental regulation fails to be obvious, and the regression coefficient of the interaction item is −0.3627. The improvement of the degree makes the marginal effect of the agglomeration effect decrease in the evolution of urbanization development. Among them, the adjustment of industrial structure has no significance under environmental regulation, and the innovative application of carbon reduction technology and the strengthening of regional cooperation are relatively significant, and their coefficients are 0.1538 and 0.4807, respectively. The interaction of industrial structure and carbon reduction technology is positive, indicating that the construction of its urbanization level can play an active and effective role in the adjustment of industrial structure applications of carbon reduction technology. The regression coefficient of regional cooperation on E-R is 0.4807, indicating that inter-regional cooperation can be accelerated with the improvement of the urbanization level, but its interaction coefficient under the 10% significance level test is −1.4693, indicating that it demands to follow with interest the scale of cooperation during the development process. Ke et al. deeply studied the spatial and temporal pattern and evolution trend of urban land use carbon emission intensity and studied the spatial and temporal pattern and evolution trend of urban land use in China from 2000 to 2017 by using the methods of kernel density estimation (KDE), exploratory spatial data analysis (ESDA) and spatial Markov chain. It was found that there are obvious differences in urban distribution rules in different forms of spatial agglomeration, and it was suggested that differentiated urban land low-carbon use patterns and carbon emission reduction policies should be formulated [46]. Improving carbon emission efficiency is the most direct and effective way to reduce pollution. Wang et al. took 31 cities in the urban agglomeration in the middle reaches of the Yangtze River as the research area and tested the role of policies in improving carbon efficiency with the help of the exponential decomposition method, super-efficiency relaxation model, and difference model in difference. The results show that the carbon emission efficiency of cities is obviously unbalanced, and the impact of regional coordinated development policies on urban carbon emission efficiency is heterogeneous. The policy effect has a negative impact on urban carbon emission efficiency through the urbanization rate and population density [47].

5. Discussion

Extensive consumption of resources and unbalanced urban development exist in the process of rapid urbanization in China. Excessive constraints and challenges restrict the quality and speed of urbanization in China. The sustainable and resource-intensive urbanization path adheres to the low-carbon urbanization construction path [48]. The study analyzes the mechanism and coupling between urbanization and carbon emissions under the background of dual-carbon and analyzes the coordination of provinces, cities and regions from the temporal and spatial dimensions. The results prove that the construction of low-carbon urbanization has a good application prospect and value, and the development of each province and city is mostly in line with the "S" and "U" development laws. The average coupling coordination degree has changed from 0.2958 in 1998 to 0.5306 in 2020. The reason for the increase in the level is mostly due to the improvement of the urbanization level of various provinces and cities. The global Moran index from 2008 to 2015 showed a clear downward trend, and its minimum value reached 0.085. The correlation trend of the degree of various provinces and cities in the spatial dimension is weakening, and the positive effect is decreasing. The local spatial index shows that the high-value areas in 2009 were mainly centered in Tianjin and Shanghai. The coupling coordination degree in Chongqing has also changed from an insignificant area to a highly concentrated area, and the coupling degree of urbanization is increasing. The reason for this result is that the difference in the level of urbanization among different provinces makes the overall spatial difference change significantly, and the bias and support of economic policies and the formulation of related environmental governance measures all make the temporal and spatial changes of the coupling coordination degree obvious [49,50]. Urbanization construction is conducive to reducing carbon emissions and has strong guidance, but its transmission mechanism and its impact relationship have not been well explored. Whether external factors such as urban population size, geographical location, economic scale, human capital, and environmental regulation will affect urban carbon emissions reduction is uncertain. Only by exploring the relationship between urban development and carbon reduction mechanism in different regions can targeted emission reduction measures be obtained. The construction of new urbanization mainly affects carbon emissions through infrastructure construction, energy efficiency and environmental regulation. Therefore, the analysis of its intermediary effect can effectively analyze the heterogeneous results of different influencing factors and the spatial relationship between urbanization level and carbon emissions. The intermediary effect indicates that the construction of infrastructure can effectively intervene in the implementation of the carbon reduction activities in the eastern region, and adjustment of energy structure can achieve a positive impact on the central region. In addition, environmental regulation reduces the marginal effect of the agglomeration effect in the course of urbanization growth. The regression coefficients of the application of carbon reduction technology and the strengthening of regional cooperation reached 0.1538 and 0.4807, and the interaction coefficient of regional cooperation under the 10% significance level test was −1.4693. The balanced and rapid development of urbanization and ecological environmental protection has increasingly become an important national strategy. Based on the principle of sustainable development, Zhang et al. conducted a coupling and co-scheduling analysis on the environmental quality (NUQ) and ecological environmental carrying capacity (EECC) of 246 prefecture-level and above cities in China's new urbanization and analyzed the differences between cities using the coefficient of variation (CV) method. The results show that the coordinated development cities are mainly concentrated in the eastern coastal areas. The center of gravity CCD is found to move from the northeast to the southwest, and the cluster positions of HH and LH (CDD main city, low; CDD surrounding cities, high) are mainly concentrated around the megalopolis, but most of the evaluated cities have not achieved coordinated development. The analysis of urban coupling coordination degree is an important measure to effectively strengthen the construction of ecological civilization in urbanization. There are certain spatial and regional differences between the results and the development of the urban coordination degree proposed in the study. The relationship between urban construction and the environment by means of coupling coordination degree can effectively provide decision-making guidance and achieve the goal of dual-carbon [51]. Shen et al. and other scholars analyzed the panel data of 5 departments in 30 provinces under the influence of a dynamic network with the help of the logarithmic mean Divisia index, and the results showed that the transfer of intensive industries in the new (host) region affected by the increase in emissions was higher than that in the original (home) region caused by the reduction of emissions. The formulation of key policies can effectively affect the industrial agglomeration and layout and thus intervene in carbon emissions [52]. Low-carbon development is an important guarantee for achieving high-quality development. Wang et al. analyzed the spatial heterogeneity of carbon emissions in counties from the perspective of land scale and selected the county economic belt in the Yangtze River basin of China for data analysis. After analyzing the geographically weighted regression model, it was concluded that the land scale has a great impact on carbon emissions, and the construction land scale has significant spatial heterogeneity [53].

Therefore, in the future development process, by improving the spatial data changes of the coupling coordination degree, paying attention to the differences in regional urbanization, and optimizing the industrial structure and inter-regional cooperation, the imbalance of China's low-carbon urban construction can be effectively improved, and the dual-carbon will be achieved faster.

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