Analysis of the Impact of Real Estate Policies on Carbon Emissions of Residential Buildings in Small and Medium-Sized Cities in China with Spatial and Temporal Heterogeneity

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Abstract. China has set a target of peak carbon by 2030 and a target of carbon neutrality by 2060. In recent years, many residential buildings in small and medium-sized cities are in a state of imbalance between supply and demand, and the task of carbon emission reduction is onerous. In this paper, the full life cycle carbon emission theory is used to calculate the carbon emission of 33 typical residential buildings in small and medium-sized cities from 2011 to 2020. In terms of time, there are two trends. The first is that the per capita carbon emission of residential buildings increases over time, while the second is the opposite. In terms of space, the regions with higher carbon emissions per capita from residential buildings are mainly distributed in the northern and eastern regions. The lower regions are mainly distributed in northwest and southwest China. In this paper, the PMC method is used to evaluate the real estate-related policies in 33 cities, and the regression analysis is carried out. The research shows that the higher the requirement of real estate carbon emission policy and the stricter the implementation, the more obvious the effect of residential carbon emission can control.

Keywords: Building carbon emission · Full life cycle · Spatio-temporal heterogeneity · PMC · Real estate policy

1 Introduction

China is entering a new journey of development in the 14th Five-Year Plan, and "achieving the carbon peak target and carbon neutral vision by 2030 and 2060". The "double carbon" target has been listed as one of the priorities of the 14th Five-Year Plan. In The 14th Five-Year Plan period, the "double carbon" target has been listed as one of the key tasks to be promoted in Chen Lida article(2021) [1]. The proportion of total building energy consumption to total social is increasing year by year. Although the average annual growth rate is gradually slowing down, the total amount is still growing in Zhou Jianjun article (2022) [2].

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2 Reviews of Literature

At present, there is no unified and accepted method for accounting carbon emissions of buildings, and the commonly used methods include input-output analysis, emission factor method and full-life method. Shen Liyin (2019) [3] used the input-output method based on the super-efficient SBM model to measure and study the efficiency of carbon emissions of residential buildings in China. Zhu Fangwei (2018) [4] used the carbon emission factor method to calculate the energy consumption and carbon emissions of public buildings in Wuhan City during the operation phase based on statistical and audit data. Chen Yi (2019) [5] selected a single building project in Tianjin and studied the whole-process carbon emissions of the single building based on the whole-life evaluation method of the building and the emission factor method. Zhang Li Chunyi (2020) [6] obtained the relevant data of Tianjin Post and Telecommunications Apartment City through field investigation and questionnaire survey, and calculated the building carbon emission of households by using emission factor method.

The Energy Consumption Committee of the China Building Energy Conservation Association released the China Building Energy Consumption Research Report (2020) at the Association's 2020 annual meeting. Two methods of measuring carbon emissions from the production of building materials were mentioned: the input-output table method and the physical consumption measurement algorithm.

Domestic scholars have conducted numerous studies on the spatial distribution and differences of carbon emissions in China, which can be divided into three levels: regional, provincial and municipal according to different study on scales. Cheng Yeqing (2010) [7] used the method provided by IPCC to calculate China's carbon emissions from 1997 to 2010, and the results of his study indicated that China's carbon intensity has a growing spatial agglomeration at the provincial scale.

At present, relevant scholars in China and abroad mostly use exponential decomposition analysis and structural decomposition analysis to study the influencing factors of carbon emissions. Yang Yanfang (2016) [8] studied the factors affecting building carbon in Beijing, and the results showed that population urbanization and per capita floor area had a large impact on building carbon emissions in Beijing. In his paper, Le Baolin (2022) [9] showed that geographic location and research and development investment differences had a significant contribution to the spatial correlation network. The smaller the difference in economic development, the stronger the network correlation. And the provinces need to develop specific measures to achieve "double carbon" according to geographic location.

2.1 Literature Review

By reviewing the existing studies in China and abroad, it can be seen that scholars have carried out rich research and exploration on carbon emissions and carbon emissions in the construction industry, and have formed conclusions with certain theoretical and practical significance. However, some problems have been overlooked in the existing studies.

1. For the calculation of building carbon emissions, the current level of research on building carbon emissions mainly focuses on the national and provincial and municipal level, but the research for building carbon emissions in third- and fourth-tier cities is relatively small at the same time. In addition, the results of building carbon emissions obtained by different measurement methods also differ greatly. Therefore, in this paper, the full life cycle theory is used to calculate the building carbon emission, and the uncertainty of the model construction, the parameter setting and analysis results is also discussed.
2. In the studies related to the spatial distribution and differences of carbon emissions, the existing studies mostly study the characteristics of regional differences of carbon emissions based on the quantitative differences of carbon emissions of carbon emission intensity, or only use methods such as Gini index and spatial correlation analysis to reveal the characteristics of spatial distribution of carbon emissions, lacking the overall presentation of spatial and temporal characteristics of carbon emissions from multiple perspectives. Therefore, this paper uses spatial visualization analysis to explore the spatial distribution and different characteristics of carbon emission intensity in the construction industry, and provides theoretical support for the coordinated low-carbon development of the construction industry from the spatial and temporal perspectives for the carbon emission distribution characteristics of the construction industry.
3. Among the existing studies on carbon emission impact factors at home and abroad, the spatial pattern of carbon emission is the first to receive attention. A large amount of related literature mostly based on inter-provincial panel data, which classifies provinces according to indicators such as total carbon emission, carbon emission intensity and per capita carbon emission, and identifies the spatial distribution pattern of carbon emission. This paper focuses on the spatial analysis from the perspective of small and medium-sized cities.

3 Research Subjects

The 2019 China Small and Medium-sized Cities Scientific Development Instruction Research Results released by the Committee on Economic Development of Small and Medium-sized Cities of the China Society of Urban Economics and the Institute for Strategic Development of Small and Medium-sized Cities, the development of small and medium-sized cities compared with 2010 is detailed.

From the research results, the number of small and medium-sized cities in China is large, occupying a large area throughout the country, while the total population in small and medium-sized cities is growing, and the requirements for elements such as environment, resources, and markets are getting higher and higher. Small and medium-sized cities become an important part of optimizing the structure of national towns. If the quality of residential-type building development in small and medium-sized cities can be improved, then it can also play a role in promoting the establishment of environmental protection and resource-saving society.

The per capita residential carbon emissions vary significantly from city to city, which is related to many factors such as the location of the city, the level of infrastructure, the quality of life and habits of residents, and urban development policies. For China, the urban characteristic of heating energy consumption significantly affects the level of residential carbon emissions. Accordingly, this study selects 33 representative small and medium-sized cities based on the principles of spatial homogeneity, diversity of demographic characteristics, and representativeness of residential vacancy based on the division of China into north and south based on the Qin ling Mountains and Huaihe rivers, as shown (Table 1) .

The carbon emission of the study city is calculated according to the method of full life cycle. The carbon emission of the four stages of building materials production, transportation of building materials, construction and operation are calculated by stages, while the carbon emission of the demolition stage is not considered. The data of the statistics of annual population and the annual newly added residential building area of each city were all derived from China Statistical Yearbook or Local Statistical Yearbook.

4 Analysis of Carbon Emission Measurement of Residential Buildings

4.1 Calculation Method and Actual Calculation Process

This study adopts the theory full life cycle. In this paper, we take Shangqiu city as an example to illustrate the process of carbon calculation for residential buildings in small and medium-sized cities.

The first step is the production stage of building materials. The main materials are hot-rolled steel bars, C30 ready-mixed concrete, C25 ready-mixed concrete, autoclaved lime-sand brick, concrete bricks, etc. The carbon emission of the stage building materials production is calculated by using Donghe Building Carbon Emission Software 2.0, and then the carbon emission per unit area is calculated. We get the carbon emissions of the new residential category of the stage of new building materials production in Shangqiu City in 2020.

The second step is the transportation phase of building materials. The CSG is the carbon emissions generated during the construction (building and demolition) phase of the building.

$$CSG = CSC \times 4\% \tag{1}$$

The third step is the construction phase.

CYX (Average carbon emissions per square meter built per year, unit: tons) = Ui (Total construction energy consumption per year, unit: tons of standard coal volume) × 2.7 (Carbon emissions per ton of standard coal, unit: tons) / S (Completed area per year unit: square meters)

$$\overline{C}YX = Ui \times 2.7/S \tag{2}$$

Table 1. Representative small and medium-sized cities

Area	Province	City
North	Inner Mongolia Municipality	Baotou City
		Erdos City
		Hohhot City
	Liaoning Province	Fushun City
	Shandong Province	Heze City
		Weihai City
		Dongying City
	Shanxi Province	Linfen City
		Xinzhou City
	Shaanxi Province	Yulin City
		Xianyang City
		Yan'an City
	Henan Province	Nanyang City
		Shangqiu City
		Xinyang City
		Zhoukou City
South	Sichuan Province	Luzhou City
	Guizhou Province	Bijie City
	Hunan Province	Xiangtan City
		Shaoyang City
	Jiangsu Province	Yancheng City
		Zhenjiang City
	Anhui Province	Huainan City
		Liuan City
	Fujian Province	Longyan City
	Zhejiang Province	Quzhou City
	Jiangxi Province	Fuzhou City
	Guangdong Province	Meizhou City
		Qingyuan City
		Zhanjiang City
		Zhaoqing City
		Maoming City
	Hainan Province	Sanya City

Carbon emissions from the construction phase per city per year CYX = $\overline{C}YX$ × S (Completed area per city per year, unit: square meters)

$$CYX = \overline{C}YX \times S \tag{3}$$

The fourth step is the operation phase.

C (Per capita domestic carbon emissions, unit: ton) = Ui (Per capita domestic energy consumption, unit: kg of standard coal) × 2.7 (Carbon emissions per ton of standard coal/ton, unit: ton)

$$\overline{C} = Ui \times 2.7 \tag{4}$$

C (Carbon emissions from the operation phase of buildings per year in each city, unit: ton) = $\overline{C}$ (Per capita living carbon emissions, unit: ton) × P (population per year in each city)

$$C = \overline{C} \times P \tag{5}$$

In the fifth step, the carbon emissions obtained from the first four steps are added up to get the total building carbon emissions of the city in that year. So, the number of the resident population of the city in that year is determined, and finally the total is divided by the population to get the building carbon emissions per capita.

According to the above steps, this paper calculates the carbon emissions of residential buildings in a total of 33 small and medium-sized cities in China from four levels. Since the data from the statistical yearbook of each city is difficult to be complete, the interpolation method is applied to fill in the missing data shows the results of carbon emission calculation for residential buildings per capita (Table 2).

4.2 Analysis of Carbon Emission Results

Time Variation Analysis of Carbon Emissions.
Using the data in the table, it is possible to classify the carbon emissions of residential-type buildings in the cities studied into the following two types, including the declining type and the rising type (Table 3).

Analysis of the Spatial Variation of Carbon Emissions.
According to the data obtained, we select three-time nodes, namely 2020, 2016 and 2011. With the help of ArcGIS10.8 software, the per capita building carbon emissions of the selected cities in three years are visualized to more intuitively show the spatial evolution law of carbon emissions. We then get the quintile bitmap of the total carbon emissions of urban residential buildings per capita. The depth of colour represents the carbon emissions of residential buildings per capita in the region. The darker the colour of the quintile bitmap is, the higher the emission level is. The colour of the region is successively represented by light and dark: lowest carbon emission level, low carbon emission level, medium carbon emission level, high carbon emission level, and highest carbon emission level.

Table 2. Per capita carbon emissions from residential buildings (Unit: ton)

City/Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Yancheng City	1.34	1.51	1.44	1.92	1.52	1.71	1.99	1.75	1.83	1.99
Zhenjiang City	1.87	2.19	2.06	2.82	4.56	2.44	1.89	2.59	2.76	2.87
Hohhot City	2.04	2.02	1.89	1.95	2.11	1.81	1.86	1.92	1.92	1.89
Weihai City	3.64	4.04	3.58	3.33	3.24	2.80	2.75	2.96	3.39	2.78
Xianyang City	0.99	0.88	1.06	0.99	1.11	1.14	1.17	1.22	1.34	1.30
Xiangtan City	2.96	3.01	3.44	3.58	3.72	3.25	3.49	3.63	3.82	3.98
Huainan City	2.31	2.39	2.97	3.09	1.87	1.84	1.40	1.49	1.36	1.37
Liuan City	1.05	1.08	1.15	1.22	1.49	1.63	4.79	1.51	1.78	1.63
Baotou City	3.08	1.93	2.04	1.81	2.25	2.31	2.94	1.93	2.18	2.17
Quzhou City	1.34	1.35	1.44	1.15	1.64	1.32	1.48	1.48	2.47	2.14
Dongying City	0.99	1.82	1.94	2.02	2.44	1.23	1.54	2.27	2.88	2.90
Linfen City	1.00	1.14	1.10	1.08	1.20	1.31	1.30	1.34	1.37	1.40
Luzhou City	1.11	1.32	1.47	1.36	1.40	1.68	1.95	2.02	1.88	2.12
Sanya City	2.14	3.44	1.54	5.93	3.80	4.88	2.83	4.01	3.06	3.76
Shangqiu City	1.90	1.73	1.45	1.44	1.30	1.10	1.34	5.30	6.19	5.19
Xinyang City	1.18	1.27	1.37	1.46	1.46	1.65	1.81	1.89	1.79	1.86
Erdos City	2.16	3.59	3.16	1.81	1.57	1.63	1.50	1.43	1.32	0.95
Meizhou City	1.79	1.87	1.91	1.91	2.18	2.08	1.48	1.49	1.39	1.42
Longyan City	1.16	1.25	1.48	1.31	1.46	1.50	2.10	1.60	2.10	2.10
Fushun City	2.05	1.92	1.86	3.57	1.60	2.89	1.50	1.63	1.47	1.54
Changzhi City	1.29	1.28	1.36	1.50	1.43	1.77	1.50	1.57	1.63	1.53
Xinzhou City	1.00	1.27	1.19	1.09	1.21	1.54	1.26	1.34	1.42	1.40
Yulin City	1.45	1.47	1.64	1.37	1.51	1.47	1.45	1.60	1.63	1.66
Yanan City	0.96	1.03	1.09	0.99	1.28	1.50	1.70	1.26	1.51	1.63
Bijie City	0.93	0.97	1.03	1.02	1.09	1.12	1.14	1.19	1.25	1.27
Shaoyang City	1.03	1.05	1.13	1.18	1.26	1.29	1.36	1.42	1.44	1.45
Fuzhou City	1.23	1.57	1.68	1.27	1.29	1.78	1.88	1.53	1.51	1.63
Qingyuan City	1.26	1.60	1.52	1.75	1.91	1.74	1.81	2.22	2.47	2.39
Zhanjiang City	1.01	1.00	1.11	1.13	1.23	1.21	1.20	1.44	1.45	1.46
Zhaoqing City	1.36	1.43	1.45	1.44	3.00	1.56	1.60	1.49	1.63	1.89
Nanyang City	0.98	1.07	1.13	1.26	1.21	1.26	1.35	1.36	1.33	1.37
Zhoukou City	1.06	1.15	1.26	1.37	1.32	1.49	1.58	1.68	1.85	1.90
Heze City	1.03	1.19	1.26	1.41	1.47	1.55	1.77	1.99	1.80	2.05

Table 3. City type table

City Type	City Name
Declining Cities	Hohhot City Weihai City Baotou City Fushun City Huainan City Changzhi City Erdos City
Rising Cities	Xianyang City Xiangtan City Shangqiu City Meizhou City Yulin City Fuzhou City Xinzhou City Yancheng City Yanan City Nanyang City Zhanjiang City Heze City Shaoyang City Bijie City Xinyang City Luzhou City Linfen City Qingyuan City Longyan City Quzhou City Zhaoqing City Zhenjiang City Sanya City Dongying City Liuan City Zhoukou City

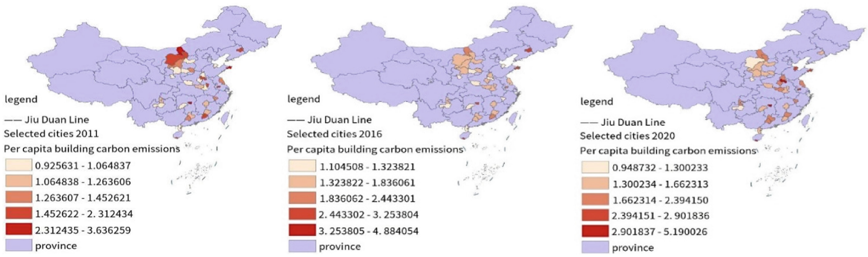

Fig. 1. Quintile variation of carbon emissions per capita from residential buildings

From the distribution of carbon emission of residential buildings per capita, it can be seen that the regions with higher carbon emission of residential buildings per capita are mainly located in the northern and eastern regions. The regions with lower carbon emissions from residential buildings are mainly located in the southwestern regions, where the economic level is lower (Fig. 1).

5 Analyses of the Impact of Carbon Emission Policies

5.1 Sample City-Related Policy Selection

The policies are researched through official government websites.

5.2 Research Methodology

PMC (policy modeling consistency) index model is a policy econometric model that aims to evaluate policies scientifically and quantitatively. According to Estrada, policy modeling is an academic or empirical study that scientifically evaluates the reasons or effects of social policies based on a variety of theories and quantitative or qualitative models in Zhanghe article (2021) [10].

The main steps of PMC modeling are: (1) Select relevant variables and identify relevant parameters (2) binary processing of each binary variable and setting parameters (3) creation of multiple input-output tables (4) calculation of PMC index, etc.

Determination of Variables.

Before determining the PMC index of real estate policies of each small and medium-sized city, the parameters for evaluating real estate policies were determined. The real estate policies of the target cities from 2011 to 2020 were compiled, and the method of text mining was used to determine the high-frequency words of all policy documents by using ROSTCM6 developed by Wuhan University, and the useless words such as "first" and "first" were excluded. The top 60 terms were selected and analyzed as shown (Table 4).

Regarding the settings of primary and secondary variables, this paper draws on the settings of real estate policy indicators by existing scholars and combines its own analytical characteristics to set a total of 9 primary indicators and 37 secondary indicators. The nine first-level indicators are: policy nature (P1); policy object (P2); policy evaluation

Table 4. List of high-frequency words

Words	Amount	Words	Amount	Words	Amount
Housing	7752	Architecture	2622	Project	1565
Construction	5279	Public	1972	People's Government	1562
Building	4390	Application	1945	Development	1550
Department	4201	Provisions	1939	Real Estate	1542
Expropriation	3750	Protection	1899	Services	1525
Management	3646	Enterprise	1797	Government	1515
Leasing	3170	Compensation	1712	Household	1424
Projects	3157	Method	1702	Urban and Rural	1327
Planning	2789	Land use	1683	Institutions	1311
Land	2774	Funds	1633	Standard	1299
Words	**Amount**	**Words**	**Amount**	**Words**	**Amount**
Retrofit	1273	According to the law	1050	Programs	891
Development	1260	Use	1045	Loans	845
Area	1208	Assessment	1038	Materials	809
Settlement	1174	Processing	975	Applicant	809
Market	1150	Purchase	961	Execution	792
Supervisor	1142	Administrative	943	Construction	779
Organization	1135	Registration	936	Commercial Housing	768
Facilities	1100	Approval	927	State-owned	760
Contracts	1093	Scope	918	Residential	755
Supervision	1074	Enhancement	907	Opinion	748

(P3); policy content (P4); policy area (P5); policy objective (P6); policy timeliness (P7); policy area (P8) and the effectiveness level (P9). The secondary variables included in the primary variables are:

(1) Policy nature (P1) contains six second-level variables, which are prediction, recommendation, identification, regulation, description, and coercion. It is used to determine whether the policy has the nature of prediction, recommendation, identification, regulation, description, and coercion.
(2) Policy target (P2) contains four secondary variables, namely, individual enterprises, financial institutions, land, and housing. It is used to judge whether the policy is targeted at enterprise individuals, financial institutions, land, and housing. And it is also used to judge whether its targeted policy plays a certain restrictive role in the development of the real estate industry. If the policy plays a certain restrictive role, then it is marked 1, and if not, then it is marked 0.
(3) Policy evaluation (P3) contains five secondary variables, which are clear objective, scientific program, adequate basis, reasonable planning, clear authority and responsibility. It is used to judge whether the policy has clear objectives, scientific programs, sufficient basis, reasonable planning, clear authority and responsibility.
(4) Policy content (P4) contains five secondary variables, which are land, taxation, urban construction, provident fund and subsidies, and property rights. It is used to determine whether the policy content involves land, taxation, urban construction, provident fund and subsidies, and property rights. Land refers to land policies (including the land premium, land supply and the land approval, etc.). Taxation refers to tax policies directly or indirectly related to the real estate market. Urban construction refers to policies related to "three old renovation" introduced in recent years. The provident fund and subsidies include the housing provident fund and the relevant policies for the payment of the provident fund and the subsidies for the admission of talents. Property rights mainly refer to the definition of land use rights. If the above-mentioned content plays a restrictive role in the development of the real estate industry, then mark 1, and vice versa mark 0.
(5) Policy area (P5) contains seven secondary variables, which are economic, social service, talent, political, public management, environment, and system. It is used to determine whether the policy involves the above seven areas.
(6) Policy objectives (P6) include four secondary variables, which are regulating house and land prices, controlling the balance of supply and demand, maintaining the order of real estate and housing security.
(7) Policy duration (P7) contains four secondary variables, which are less than one year, one to three years, three to five years, and more than five years. It is used to judge the length of time of policy implementation.
(8) Policy area (P8) contains one secondary variable. Since the research object of this paper is the real estate policy of small and medium-sized cities, the areas of the policy action are all local counties.

(9) Policy level (P9) contains a secondary variable. Since the research object of this paper is the real estate policy of small and medium-sized cities, the policy enactment unit is selected as the local people's government.

The variables of the real estate policy PMC index model are set in Table 5, and the multi-effective inputs and outputs are shown in Table 6.

PMC Index Calculation.
The secondary indicators are scored according to the content othe real estate policy, using a binary algorithm with a value of 0 or 1. It should be noted in particular that P7 = 1 when the policy is more than 5 years old.

$$X \sim N[0, 1] \tag{6}$$

$$X = X_R : [0, 1] \tag{7}$$

$$X_t = \sum\nolimits_{j=1}^{n} \frac{X_{\text{tj}}}{T(X_{tj})} t, j = 1, 2, 3, 4, 5 \ldots\ldots \tag{8}$$

$$PMC = [X1\left(\sum\nolimits_{i=1}^{6} \frac{X1i}{6}\right) + X2\left(\sum\nolimits_{i=1}^{4} \frac{X2i}{4}\right) X3\left(\sum\nolimits_{i=1}^{5} \frac{X3i}{5}\right)$$

Table 5. Variable setting of PMC index model of real estate policy

Primary variables	Secondary variables
P1: Nature of the policy	P1:1 Prediction; P1:2 Suggestions; P1:3 recognition; P1:4 Regulation; P1:5 description; P1:6 mandatory
P2: Policy object	P2:1 Corporate individuals; P2:2 Financial institutions; P2:3 Land; P2:4 House
P3: Policy evaluation	P3:1 Clear goals; P3:2 protocol science; P3:3 with sufficient evidence; P3:4 Reasonable planning; P3:5 Clear rights and responsibilities
P4: Policy content	P4:1 Land; P4:2 Tax; P4:3 Urban construction; P4:4 Provident fund and subsidy; P4:5 Property rights
P5: Policy areas	P5:1 Economy; P5:2 Social services; P5:3 Talent; P5:4 Politics; P5:5 Public administration; P5:6 Environment; P5:7 system
P6: Policy objectives	P6:1 Control of housing prices and land prices; P6:2 Control the balance between supply and demand; P6:3 Maintain the real estate order; P6:4 Housing security
P7: Policy prescription	P7:1 greater than 5P7:2 3——5years; P7:3 1——3years; P 7:4 is less than 1
P8: Policy area	Role of districts and counties
P9: Policy hierarchy	Released by local government

Table 6. Multi-effect input-output table

Primary variables	Secondary variables
P1	P1:1, P1:2, P1:3, P1:4, P1:5, P1:6
P2	P2:1, P2:1, P2:3, P2:4
P3	P3:1, P3:2, P3:3, P3:4, P3:5
P4	P4:1, P4:2, P4:3, P4:4, P4:5
P5	P5:1, P5:2, P5:3, P5:4, P5:5, P5:6, P5:7
P6	P6:1, P6:2, P6:3, P6:4
P7	P7:1, P7:2, P7:3, P7:4
P8	P8
P9	P9

$$+X4\left(\sum_{i=1}^{5}\frac{X4i}{5}\right)+X5\left(\sum_{i=1}^{7}\frac{X5i}{7}\right)+X6\left(\sum_{i=1}^{4}\frac{X6i}{4}\right)$$
$$+X7\left(\sum_{i=1}^{4}\frac{X7i}{4}\right)+X8\left(\sum_{i=1}^{1}\frac{X8i}{1}\right)+X9\left(\sum_{i=1}^{1}\frac{X9i}{1}\right) \quad (9)$$

5.3 Policy Regression Analysis

In order to investigate the impact of real estate policies on residential carbon emissions in different places, we select typical cities for analysis. Under different scenarios, carbon emissions change year by year, with Weihai City as the representative of the declining category and Dongying and Heze as the representative of the rising category. We conducted regression analysis on the PMC value of real estate policies and the carbon of residential buildings in each city during 2011–2020.

Data Source.
Through the people's government of each city and Guoxin Real Estate Information network, we searched their real estate policies from 2011 to 2020 and evaluated them (Table 7).

We scored real estate-related policies of Weihai City from 2011 to 2020, and the PMC values are shown in the table below (Table 8).

Regression Analysis.
Using SPSSAU calculation software, the real estate policies and per capita residential building carbon emissions of four representative cities in Weihai, Dongying and Heze from 2012 to 2020 are analyzed by regression analysis. Through the regression analysis, we found that PMC value was negatively correlated with per capita residential building carbon emissions, and the regression analysis results were significant (Table 9).

Table 7. List of policies of Weihai City 2011–2020

Year	Policy name
2011	Notice on adjusting the deposit base and proportion of housing provident Fund in Weihai City in 2011, etc.
2012	Opinions of Weihai Municipal People's Government on further standardizing land use, etc.
2013	Opinions on the implementation of housing expropriation and compensation on state-owned land in Weihai City, etc.
2014	Notice of Weihai Municipal People's Government on the adjustment of land level and benchmark land price in Weihai urban area, etc.
2015	Notice on further strengthening Weihai urban commercial housing presale funds supervision, etc.
2016	Notice on paid use of allocated land in Weihai City, etc.
2017	Notice on the revision of *Implementation Rules of Housing Provident Fund Loan of Weihai Housing Provident Fund Management Center*, etc.
2018	Weihai City People's Government Office on strengthening conservation and intensive land use opinions, etc.
2019	Notice on the issuance of *Measures for the Implementation of Weihai Urban Housing Security Family Rental Subsidies*, etc.
2020	Notice of Weihai Municipal People's Government on the adjustment of land level and benchmark land price in Weihai urban area, etc.

Table 8. Real estate policy PMC value of Weihai City from 2011 to 2020

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
P1	0.50	0.50	0.67	0.50	0.50	0.50	0.67	0.50	0.67	0.50
P2	0.25	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.25	0.75
P3	0.80	0.80	1.00	0.80	1.00	0.80	1.00	1.00	1.00	0.80
P4	0.20	0.20	0.40	0.40	0.40	0.40	0.40	0.40	0.00	0.60
P5	0.43	0.43	0.57	0.43	0.57	0.57	0.86	0.57	0.43	0.43
P6	0.75	0.75	0.75	0.75	0.75	1.00	1.00	0.75	0.75	1.00
P7	1.00	0.75	0.75	1.00	0.75	1.00	1.00	0.75	1.00	0.75
P8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SUM	5.93	5.93	6.64	6.38	6.47	6.77	7.42	6.72	6.10	6.83

Table 9. Linear regression analysis table

City	Weihai City		Heze City		Dongying City	
Time	Per capita building carbon emissions (y)	PMC(x)	Per capita building carbon emissions (y)	PMC (x)	Per capita building carbon emissions (y)	PMC (x)
2011	/	/	1.03	6.77	0.99	6.83
2012	4.04	5.93	1.19	6.58	1.82	6.75
2013	3.58	6.64	1.26	6.39	1.94	6.63
2014	3.33	6.38	1.41	6.38	2.02	6.52
2015	3.24	6.47	1.47	6.32	2.44	6.27
2016	2.80	6.77	1.55	6.32	1.23	6.91
2017	2.75	7.42	1.77	6.19	1.54	6.83
2018	2.96	6.72	1.99	6.07	2.27	6.72
2019	3.39	6.10	1.80	6.30	2.88	6.30
2020	2.78	6.83	2.05	6.38	2.90	6.29
Linear regression result	$y = 8.516 - 0.807 \times x$		$y = 10.394 - 1.388 \times x$		$y = 17.37 - 2.326 \times x$	
p	0.007		0.007		0.001	

6 Policy Recommendations

(1) From the PMC evaluation results of the above three cities. Both rising and falling cities have policies with higher PMC values. From the perspective of policy content, the regulation content of policies with high PMC value is diversified, involving finance, land, tax and other aspects, which can achieve clear and scientific objectives, so as to stabilize the real estate market, housing price and land price, and balance the whole market. The comprehensive control policy has played a very important role in stabilizing the real estate market, housing prices and land prices. The government needs to introduce more comprehensive real estate policies to control the production of real estate buildings that are not suitable for cities and the overheated development of real estate, so as to control the carbon emissions of buildings.

(2) From the above evaluation results, it can be seen that measures such as regulating land price, strengthening the government's role in regulating land, reducing housing provident fund, carrying out demand-side reform, expanding real estate marketization, and increasing rental housing guarantee can promote the healthy development of the real estate industry and reduce the non-green development behaviors in the development of the real estate industry.

7 Conclusions

Through this study, the carbon emission of residential buildings in some small and medium-sized cities in China from 2011 to 2020 is calculated, and the law of change of urban residential building carbon over time is obtained.

(1) The results of calculating the per capita residential building carbon are found that different cities show different trends of change. The first category of cities shows a gradual increase in per capita residential building carbon emissions over time, and the second category of cities show a gradual decrease in per capita residential building carbon emissions over time.
(2) During the study, it shows that many factors affect the carbon emissions of residential buildings in cities, including the amount of real estate construction, the human characteristics of cities, the development of urban GDP, the geographical location of cities, the construction process and the policy of building carbon emissions and many other factors. But the real estate policy plays an important role in regulating the amount of real estate construction by standardizing regulations in an authoritative form.
(3) We study urban real estate policies from 2011 to 2020, adopt PMC method, quantify their policy contents, score whether the policies can control the overheating development of the real estate market, and provide relevant basis for the government to macro-control the real estate market and formulate real estate policies.

The shortcomings of the research process are mainly divided into three points. First, there are not enough data and the data results are somewhat contingent. Secondly, in the process of calculating building carbon, the calculation-related materials are missing, and the calculated values can only be averaged within a reasonable range. Thirdly, the analysis of influencing factors is not thorough enough, and numerous factors other than policy influence will have an impact on the carbon emissions of residential buildings, which will be further improved in the subsequent.

References

1. Chen Lida. (2021) Research on macro-control to promote the development of real estate market in third-tier and fourth-tier cities [J]. Housing and Real Estate, (36):8–9.https://kns.cnki.net/kns8/defaultresult/index
2. Zhou Jianjun, Long Ping. (2022) Financial resources mismatch, the housing price and high-quality economic development: Based on spatial econometric model analysis [J]. Financial Theory and Practice. 99–105. https://doi.org/10.16339/j.cnki.hdxbcjb.2022.02.013.
3. Shen Liyin, Zhu Mengcheng, Wu Ya. (2019) Measurement of carbon emission efficiency of residential buildings in China [J]. Urban Problems, (10): 53 -- 62. https://doi.org/10.13239/j.bjsshkxy.cswt.191006
4. Zhu Fangwei, Zhang Chunzhi, Chen Yanhua, Yu Zhongyi. (2018) Study on carbon emission of Wuhan public Buildings inthe operation stage [J]. Hvac,48(12):71–76. https://kns.cnki.net/kns8/defaultresult/index
5. Chen Yi, Zhang Jian, Song Chen. (2019) Study on carbon emission of green buildings during their whole life cycle: A case study of the new business housing project of Tianjin Architectural Design Institute [J]. City, 226 (1): 77 -- 81.https://kns.cnki.net/kns8/defaultresult/index

6. Zhang Li Chunyi, Sun Qizhen, Wu Haotian, Xu Hailin, Du Mengge, Yuan Dachang.(2020) The Relationship between carbon emission and Living environment in Urban residential areas: A case study of Xinmingyuan Residential area in Chengnan Jiayuan and Xinyuan Village, Tianjin [J]. Building Energy Conservation,48(01):93–101 + 107. https://kns.cnki.net/kns8/defaultresult/index
7. Cheng Yeqing, Wang Zheye, Ye Xinyue, Wei Yehua. (2014) Carbon emission intensity of energy consumption and its Influencing factors in China [J]. Journal of Geographical Sciences, 24 (04): 631–650.https://doi.org/10.11821/dlxb201310011
8. Yang Yanfang, Li Huifeng, Zheng Haixia. (2016) Research on influencing factors of building carbon emission in Beijing [J]. Ecological Economy,32(01):72–75. https://doi.org/10.3969/j.issn.1671-4407.2016.01.015
9. Le Baolin, Xu Shaojun. (2022) Spatial correlation network structure and influencing factors of carbon emission fromthe construction industry in China [J]. Journal of Zhejiang Sci-Tech University (Social Science Edition),48(05):493–501. https://kns.cnki.net/kns8/defaultresult/index
10. Zhang He, Ya Meng, Wang Rui, ZhangJianxun. (2021) A comparative study on carbon emission and influencing factors of urban residential buildings of different sizes [J]. Building Energy Conservation, 49(03):1–8. https://doi.org/10.3969/j.issn.2096-9422.2021.03.001