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Article

How Land Transactions Affect Carbon Emissions: Evidence from China

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Abstract: Land use change has become the second-largest source of greenhouse gas emissions after fossil energy combustion. In the context of developing a low-carbon economy, it is important to study how to achieve energy savings and emission reduction by adjusting land prices, and transforming land trading methods and land use types. Utilizing a balanced panel dataset about 291 sample cities in China, during the period of 2010–2016, this paper divided land transactions into three dimensions: land transaction price, land transaction modes, and land transfer structure; then employed a fixed-effect model to investigate the relationship between land transactions and carbon emissions. On top of this, we further analyzed the moderating role of economic development level and emission reduction policy. This study found that land transaction price can significantly inhibit carbon emissions; the amount of land sold by auction and listing has a stronger inhibitory effect on carbon emissions than by bidding; the higher the transfer proportion of industrial land, the higher the carbon emissions, while the transfer proportion of residential land is significantly negatively correlated with carbon emissions; the moderating mechanism shows that the level of economic development and emission reduction policy can play a moderating role in the relationship between land transactions and carbon emissions, but the moderating effect of emission reduction policy is limited, only existing in the relationships between land transaction price, the amount of listed land, and carbon emissions.

Keywords: land transactions; carbon emissions; economic development level; emission reduction policy

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1. Introduction

The emission of greenhouse gases dominated by carbon dioxide has caused frequent global extremes such as rising sea levels, acceleration of glacial melting, and polarization of drought and flood, which have seriously affected many people's daily lives. The pressure to reduce carbon emissions has been raised to an unprecedented level [1]. Under this circumstance, a social consensus has been reached to promote low-carbon development. To strengthen the response to the threat posed by climate change, 195 countries signed the Paris Agreement in 2015 to make unified arrangements for global action to address climate change after 2020, which pointed out the need to limit the global average temperature increase to 2 °C above pre-industrial levels and to work toward limiting warming to 1.5 °C [2,3]. Meanwhile, China is one of the major contributors to global carbon emissions [4,5], and has pledged to achieve the double carbon goal of carbon peak in 2030 and carbon neutralization in 2060 to reduce carbon emissions [6].

Since the carbon reduction target has been put forward, the issue of carbon emission reduction has turned into a new research focus in academic fields. Reviewing the previous literature, scholars' researches on carbon emission reduction are mainly reflected in three perspectives: Firstly, they focused on urban economic development. There were many academic studies on the relationship between carbon emissions and urban economic development [7–9], and Begum and Pereira [10] empirically found that urban economic growth went against carbon dioxide emissions in Malaysia in the long run. Therefore, it is necessary to reduce carbon emissions while maintaining long-term economic growth with the help of relevant low-carbon technologies.

Wang et al. [11], based on the 12-year data of 28 provinces in China, found that there was a bidirectional causality between carbon dioxide emissions, energy consumption and urban economic development. Limiting carbon dioxide emissions may hinder China's urban economic development to a certain extent. Similarly, Nie and Xing [12] have reported that economic growth positively related to carbon emissions in China, while Mushtaqa et al. [13] have argued that the relationship between economic development and carbon emissions in China was nonlinear and the empirical results have confirmed the existence of an environmental Kuznets curve (EKC) hypothesis.

Secondly, the distribution characteristics of carbon emissions were analyzed from the perspectives of geography and space. Falahatkar and Rezaei [14] believed that the spatial distribution characteristics of carbon emissions were closely related to urban morphology. The more complex and fragmented the urban morphology is, the more carbon dioxide emissions can be increased.

Zhang et al. [15] analyzed the spatial pattern of carbon emissions in the Shandong province of China from the two dimensions of time and space. The empirical results showed that there were significant spatial differences in urban carbon emissions in Shandong province. Zhang et al. [16] used the visualization method of the geographic information system (GIS) to analyze the overall differences, along with temporal and spatial evolution features, of carbon emissions in eight economic regions of China in 14 years. The results showed that the levels of energy consumption, industrialization and technological development were the main driving factors that affected the spatial heterogeneity pattern of regional carbon emissions, and regional carbon emission reduction needed to be implemented in differentiation schemes.

Su et al. [17] analyzed the evolutionary characteristics of urban networks and carbon emissions in the sample cities from 2010–2019 based on panel data of 47 cities in southwest China. The empirical results indicated that the spatial and temporal distribution characteristics of urban networks and carbon emissions were highly consistent in rapidly developing regions, the impact of urban networks on carbon emissions was two-sided, with urban networks exhibiting a stronger promoting effect in rapidly developing regions.

Thirdly, current studies analyzed the factors that affected carbon emissions. Pan and Zhang [18] used the extended STIRPAT model to investigate the impact of various factors on US carbon emissions from 1960 to 2014. The research results showed that the proportion of commodity trade in gross domestic product (GDP) was the most important factor affecting American carbon emissions.

Wang et al. [19] in view of the "energy–economy–carbon emissions" hybrid input-output analysis framework, the structural decomposition analysis of the influencing factors of carbon emission in Guangdong province was carried out. It turned out that economic and population growth were the main direct drivers of the increase in carbon emissions, while international and provincial trade were the indirect drivers, and the increase in carbon emissions was mainly concentrated in energy and carbon intensive industries. It is worth noting that the sixth report of the IPCC of the United Nations government panel on climate change claimed that the annual average of CO_2 emissions from 2010–2019 is at the highest level in human history. In proportional terms, this decade accounts for 42% of cumulative global net CO_2 emissions since 1850 [20]. From the second industrial revolution to the beginning of the 21st century, the carbon dioxide emissions caused by land use change accounted for 1/3 of the total carbon dioxide emissions affected by human activities [21], and the contribution rate to the greenhouse effect was about 24% [22].

Land transactions are the main form of land development and utilization. The existing researches focused on land transactions can be divided into land supply and land demand, according to different subjects. The research on land supply is mainly concerned with the land supply structure [23–25], factors affecting land supply [26], and land supply strategy [27,28], mostly from the macro level. The research on land demand is mainly focused on the prediction of land demand [29,30], in order to achieve better land supply, mostly from the medium and micro level. Unfortunately, at present, there are few studies that integrate land transactions and carbon emissions into the framework as a whole. The existing studies have mentioned that land transactions have a certain impact on carbon emissions [31–33]. These studies provide a certain theoretical basis for this paper; we can further explore how this relationship changes in different contexts, as well as complement existing studies on impact mechanisms to some extent.

Inspired by this, using the panel data of 291 prefecture level cities and above in China from 2010 to 2016, this paper attempts to divide land transactions into three dimensions: land transaction price, land transaction modes, and land transaction structure; specifically analyzes the relationship between land transactions and carbon emissions; and tests the moderating effect of this relationship from the two dimensions of time and spatial. This paper makes three contributions to the existing literature. First, current scholars have conducted a large number of studies on the relationship between land transactions and carbon emissions at the national levels [34,35] and regional levels [36,37], while, based on the prefecture level cities and above, this paper studies the relationship between the three dimensions of land transactions and carbon emissions from the urban level. Second, in terms of the three dimensions of land transactions, this paper examines the impact of the land transaction modes on carbon emissions, forming a more complete analytical framework about land transactions. Third, it sets out from the emission reduction policy in the time dimension and the economic development level in the spatial dimension, further analyzing the impact mechanism between land transactions and carbon emissions systematically. The rest of the paper is arranged as follows: the second part is the theoretical review and hypothesis research, the third part is data and methodology, the fourth part is the analysis of empirical results, and the fifth part is the conclusion and policy suggestions.

2. Literature Review and Hypotheses

2.1. Land Transaction Price and Carbon Emissions

Cities are core areas of carbon emissions reduction and CO_2 sources [38], accounting for 2% of the world's area but producing 75% of the world's total carbon dioxide [39]. China has been the world's highest CO_2-emitting country since 2006 [40], and statistics show that the process of urbanization in China has increased speedily from 35.87% in 2000 to 63.89% in 2020, which has exceeded the world average since 2013 (World Bank, 2017). Rapid urbanization has increased energy consumption, surely making it one of the main contributors to CO_2 emissions, leading to worsening environmental pollution, and a shortage of resources. So, accelerating environmental protection by reducing CO_2 emission effectively is of great urgency. Since 2012, China has proposed the construction of ecological civilization, which includes the reduction of carbon emissions [41], the urbanization scale and expansion speed has been restricted to some extent. The process of urbanization is inseparable from the use of land resources, if the land transaction price remains at a high degree, the land transactions number will be mostly reduced, as well as the scale and speed of urban expansion restrained. Also, the high price leads to many real estate companies or other economic entities lacking sufficient funds to bid for land transactions, especially for small-sized real economic entities. In the process of construction and after completion, a building itself would emit a lot of carbon dioxide. Less land corresponds to fewer construction activities, and the amount of carbon emissions from buildings would be reduced, too. So, with the help of a high land transaction price and low land transaction level, the urban CO_2 emissions will decline. To summarize, we propose the following hypothesis:

Hypothesis 1 (H1). *Land transaction price can effectively reduce urban carbon emissions.*

2.2. Land Transaction Modes and Carbon Emissions

Land supply in China is by different means of auctions; the government has the ownership of land. Developers mainly trade vacant land in a market, and manage land development risk actively for profits [42]. Once there is vacant land available, the government makes an announcement to the public, and the land is sold to whomever bids at the highest price in an auction. Land transactions are also listed, without on-the-spot bidding. In another method each participant has to submit his bidding price for the land without knowing the others' bidding prices—as soon as the bid is submitted, it cannot be modified. Therefore, the applicant has only one chance to put forward the price. Unlike in the methods of auction and listing, the bids of all parties are made public in real time or "quasi real time". The delay in the disclosure of bidding conditions increases the possibility of black box operation [43,44]—the whole process can be additionally seen as a first-price sealed auction [45]. The evaluation standard for the final success of the bidding transaction needs to comprehensively evaluate a series of factors, such as the bidder's reputation and competitiveness, which is not necessarily obtained by the highest bidder. Therefore, compared with the two land transaction methods of auction and listing, bidding is a more operable and milder form of competition. If the assignees obtain the ownership of land use through black box operation, they will use the land to the greatest extent regardless of the environmental carrying capacity. Therefore, the more land transactions are conducted by bidding, the less it can effectively reduce urban carbon emissions. Thus, we propose the following:

Hypothesis 2 (H2). *Compared with land transactions by auction and listing, the urban carbon emissions inhibitory effect of bidding is weaker.*

2.3. Land Transfer Structure and Carbon Emissions

The tax-sharing system reform in 1994 caused a mismatch between financial and administrative powers of local governments, excessive dependence on land finance and burdened the local governments with debts [46,47]. As a compromise, the central government allowed local governments to alleviate the imbalance of revenue and expenditure by carrying out land transactions, which led to fierce competition for attracting investment under the pressure of finance and taxation [48]. The monopoly of state-owned construction land supply is in the hands of local governments. Because industrial and commercial land can bring huge investment and increase local fiscal revenue in the short term, these have become the government's investment attraction tools. Due to the great promotion potential of industrial land to the local industrialization process, making it the first choice of investment attraction tools [49]. Under the multiparty game, the three bottom-line competitions between industrial land and commercial land came into being, including scale bottom-line competition, transfer-price bottom-line competition, and investment-quality bottom-line competition [50], resulting in the gradual separation of the supply scale and manner of local industrial land and commercial land from the preset optimal allocation mode, forming the phenomenon of land mismatch. The competition between the bottom line of scale and the bottom line of transfer price has caused a serious imbalance between the supply of industrial land and commercial land, hindered the green and healthy development of the region, and increased the emissions of industrial pollutants along with carbon dioxide. According to the standard for classification and planning of urban land for construction (GB 50137-2011), residential land accounts for no more than 40% of urban construction land, while industrial land accounts for no more than 30%. Under the international standard, the supply area of industrial land and commercial land is about 1:2, but the reality is that the ratio of the two is about 2:1 in many cities [51], which has seriously broken through the national standards. Limited by the total amount of construction land, local governments use the land strategy of large-scale low-cost supply of industrial land and limited high-price supply of commercial land to operate the city, squeezing the supply scale of residential land. Over time, the urban development land structure has become unbalanced, resulting in the mismatch between supply and demand of "population, land and housing", which seriously affects the urban living environment, leading to high carbon emission [52,53]. Urban residential land has high requirements for greening rates, so as more residential land is traded, the greening rate of the city will be improved to a certain extent, and carbon dioxide emissions will be reduced. Because of the existence of price bottom-line competition, the transfer prices of industrial land and commercial land obviously deviate from the actual market value. There is the possibility of "land speculation" by the land demander [26], actively rent-seeking behavior from the local government, and efforts to reduce the environmental protection access threshold and land use cost by high-energy-consuming and high-polluting enterprises. For local governments to meet the needs of a land investment attraction, they pay more attention to the investment attraction scale rather than quality in the purpose of competing for the bottom lines of scale and transfer price, and use the land transactions' income to improve the infrastructure construction of industrial parks and commercial areas, improving the urban business environment to attract the next batch of rent-seeking land demanders, forming a vicious circle. The supply–demand behavior directly leads to the accumulation of a large number of medium and low-tech manufacturing enterprises with high energy consumption, backward technology, and bleak development prospects on the urban land, and hinders the agglomeration and development of high-tech enterprises with new energy, new technology, and green environmental protection. Therefore, we propose the following hypothesis:

Hypothesis 3 (H3). *The mismatch of urban industrial and commercial land can increase urban carbon emissions, while the higher the proportion of urban residential land transactions, the less urban carbon emissions there could be.*

2.4. The Moderating of the Level of Economic Development

The level of economic development is a symbol to measure the potential and state of urban development, but the environmental problems brought by economic development always threaten the high-quality sustainable development of the city [54]. Better land planning and utilization can improve the environmental carrying capacity of cities and help to reduce the pressure of urban environment [55]. Moreover, after the economic development reaches a certain degree, environmental protection will be put on the agenda. Cities with high economic development levels have greatly improved their resilience and resistance in the face of sudden and mild shocks by investing in ecological environment treatment, updating resource development and utilization technology, and urging residents to change their living habits [56,57]. Furthermore, China's large-scale land finance ensures that local governments have the ability to support local land financial expenditure [58]. Therefore, the higher the level of economic development, the more ability local governments have to attract the agglomeration of green enterprises by improving infrastructure construction and the level of public services, the stricter their land planning will be. By raising the land transaction price, it restricts land transactions of highly polluting and high-energy-consuming enterprises to a certain extent, amplifies the price effect of land transactions, and further enhances the inhibitory effect of land transaction price on carbon emissions.

After the central government promoted the market-oriented reform of land transfers, the use of "bidding, auction and listing" for land transactions has occupied an absolutely dominant position in the land transfer market. However, the local governments have not given up intervention in the land transfer market [59]. Local governments possess greater discretion in the transfer of "bidding, auction and listing", especially bidding and listing. Compared with the bidding, which has complex procedures, and the auction, which requires on-the-spot bidding; in most cases, listing without on-the-spot bidding has quickly become the most favored land transaction method of local governments, even if listing often means a lower land transaction price, more corruption, and land violation [60]. In order to minimize the negative impact on their own performance and win the political championship, local governments must make room for auction and bidding. Due to the development of economic level, the relationship governance of the government is more transparent, and the demand for land is also increasing.

Although land transaction by auction has the highest degree of marketization is the most transparent, it has damaged the hidden income of some local officials to a certain extent, as, for the main officials, better political performance and smooth career life are the most important goals [61]. The higher the level of economic development, the more financial resources the local governments have to ensure the smooth operation of the local bureaucratic system. In order to guarantee that they are well-positioned in the promotion competition, the local governments will advocate for land transactions by auction more frequently, reducing the possibility of black box operation and weakening intervention in the land market; while the bidding transaction method using the principle of comprehensive evaluation will be less adopted. Therefore, the higher the level of economic development, the three land transaction methods have a stronger negative effect on carbon emissions, among which the moderating effect between bidding and carbon emissions is the weakest.

A successful industrial land transaction not only means that the government can obtain a considerable land transfer fee, but also represents the establishment of new industrial investment projects. The local government takes advantage of broader market demand to achieve the effects of economic scale expansion, increased employment opportunities and fiscal revenue, directly promoting the local current economic growth rate simultaneously [62,63]. However, with the improvement of the level of economic development, the government's awareness of environmental protection has been continuously strengthened. In order to attract as much industrial investment as possible, suitable for its own development stage, more and more urban governments with high economic development have begun to provide supporting environmental protection infrastructure to industrial enterprises to reduce environmental pollution as much as possible.

Therefore, although industrial land accounts for an increase in the total amount of traded land, its positive impact on carbon emissions is greatly weakened; more importantly, with the continuous improvement of economic level, more and more enterprises are no longer limited to the local market. Hence, many commercial projects have become similar to industrial projects, and the suitable investment location is no longer the only one, which greatly weakens the location monopoly of commercial land, giving commercial land the same nature as industrial land. Similarly, cities with higher levels of economic development will regulate the introduction conditions of enterprises and reduce the pollution to the environment as much as possible. For this reason, the positive relationship between the increase of commercial land and the amount of carbon emissions will be weakened. For residential land with high greening requirements, with the continuous promotion of national civilized city construction, cities with higher economic development level are more motivated to provide excellence environment with reasonable planning and harmony with the living environment, which will greatly enhance its inhibitory effect on carbon emissions.

To sum up, this paper puts forward the following three hypotheses:

Hypothesis 4 (H4a). *The level of economic development can enhance the negative relationship between land transaction price and urban carbon emissions.*

Hypothesis 4 (H4b). *The level of economic development plays a negative moderating role among the relationship of three land transaction modes and urban carbon emissions, while the moderating effect in the relationship between land transactions by bidding and carbon emissions is weaker than that of the other modes.*

Hypothesis 4 (H4c). *The level of economic development negatively moderates the negative relationship between the proportion of residential land and urban carbon emissions, while it weakens the positive relationship between the proportion of industrial, commercial land, and carbon emissions.*

2.5. The Moderating of the Emission Reduction Policy

Carbon emissions have negative externalities. The public goods attribute of the atmosphere often leads to the excessive use of environmental resources, which determines the necessity of policy intervention [64]. Facing the increasingly severe environmental situation, the Chinese government has launched a new pollutant emission reduction policy with the "leadership responsibility system" as the core during the 11th Five-Year Plan period, including the emission regulations of greenhouse gases. The emission reduction policy mainly plays the role of environmental regulation through structural effect, technical effect, and allocation effect.

In terms of the structural effect of emission reduction policy, environmental regulation can affect the market structure by drawing up strict production standards and setting market access thresholds [65], and further drive the optimization and adjustment of industrial structure. Industrial structure determines the industrial layout of energy consumption and carbon emissions to a considerable extent, and the evolution of industrial structure is not only the process of replacing the combination of production factors, but also reducing pollutant emission and improving energy efficiency [66,67]. On the one hand, according to the weak Porter hypothesis [68], environmental regulation can have an incentive effect on industries or enterprises that are relevant to be regulated, so as to: optimize and improve industrial structure, business decision-making, R&D innovation and production technology [69,70]; guide and promote the transition of industries or enterprises from producing high-pollution-intensive products to green products; and reduce carbon emission intensity. On the other hand, environmental regulation increases the cost of pollution treatment and production factors by internalizing environmental externalities. If enterprises do not transform and upgrade in time, they may be forced to withdraw from the market. This mechanism of survival of the fittest gives enterprises internal incentives for industrial structure adjustment, so as to promote regional carbon emission reduction.

In terms of the technical effect of emission reduction policy, the Porter hypothesis points out that appropriate environmental regulation can stimulate high-energy-consuming and high-polluting enterprises to improve production technology to some points [71], and the pollution treatment cost can be compensated by the first mover advantage formed by technological innovation, resulting in an innovation compensation effect [68]. Under the theoretical framework of the Porter hypothesis, although the implementation of greenhouse gas emission reduction policy can lead to the increase of pollution treatment cost of enterprises, as the main body pursuing the maximization of interests, enterprises will have the motivation to increase the investment in innovative resources and carry out green innovation activities after reassessing their business conditions, and the pressure of environmental cost can be greatly relieved. In the long run, technological innovation can improve production efficiency and reduce the negative externality of environmental pollution. It can not only help enterprises obtain a sustainable competitive advantage, but also reduce pollution emissions under the given output, which is conducive to regional carbon emission reduction.

In terms of the allocation effect of emission reduction policy, Costantini [72] empirically shows that the environmental regulation policy will promote the region to gradually form the advantage of attracting capital, labor, enterprises, and other resources under the theoretical framework of the Porter hypothesis, which will help to improve the efficiency of regional resource allocation. In addition, the resource allocation effect of environmental regulation is also reflected in the use of production factors within enterprises and the allocation of production factors among enterprises at the micro level. For one thing, appropriate environmental regulation policies will guide the flow of production factors to high-productivity enterprises in the region [73], improve their market share at the output end, and reduce the availability of government-biased subsidy policies for high-pollution enterprises; for another, the effectiveness of carbon emission reduction policies is affected by the internal resource allocation capacity of enterprises and the technical level of production factors [74]. Enterprises with high energy consumption and high pollution will actively implement a series of environmental protection policies such as carbon emission reduction, and use low-carbon and eco-friendly essential productive factors or update and introduce green, eco-friendly equipment in the short term [75]. In the long run, enterprises prefer to develop and configure green production technologies and integrate high-quality production factors to improve energy efficiency and achieve the purpose of regional carbon emission reduction.

To sum up, the emission reduction policy can produce structural effects, technical effects, and allocation effects through environmental regulation, which are conducive to regional carbon emission reduction. So, we put forward the following hypotheses:

Hypothesis 5 (H5a). *The emission reduction policy can enhance the negative relationship between land transaction price and urban carbon emissions.*

Hypothesis 5 (H5b). *The emission reduction policy plays a negative moderating role among the relationship of three land transaction modes and urban carbon emissions, while the moderating effect in the relationship of land transaction by bidding and carbon emissions is weaker than that of the other modes.*

Hypothesis 5 (H5c). *The emission reduction policy negatively moderates the negative relationship between the proportion of residential land and urban carbon emissions, while it weakens the positive relationship between the proportion of industrial, commercial land, and carbon emissions.*

Based on the former theoretical hypothesis derivation and related mechanism analysis, we have drawn the research framework of this paper, as shown in Figure 1.

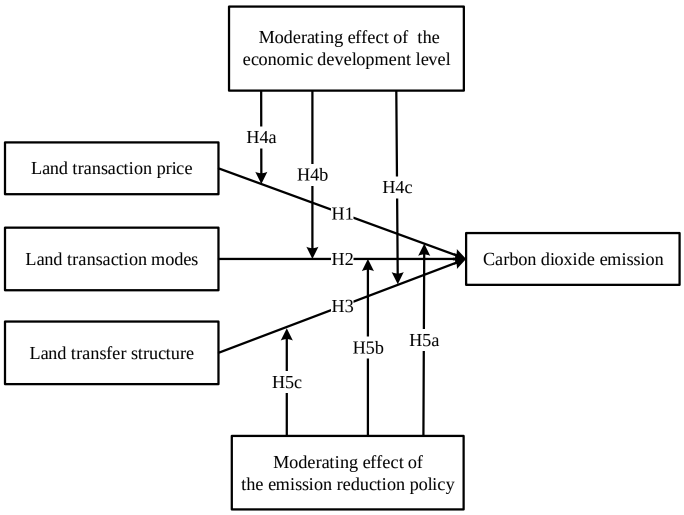


Figure 1. Research framework of this paper.

3. Study Area, Data, and Methodology

3.1. Study Area

Figure 2 shows the study area map, where the green part represents the study area of this paper, covering 291 prefecture level cities and above. Most of the sample cities are distributed in the east and central China, while the sample cities in the west are less distributed.

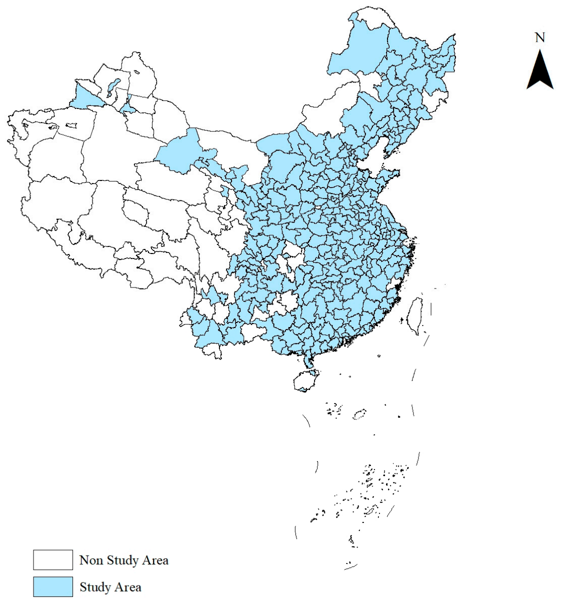


Figure 2. Study area map.

3.2. Data and Sample

This paper selects 291 prefecture-level cities and above in China from 2010 to 2016 as the sample data at a balanced panel, mainly including land transaction data, carbon emission data, and relevant data at the urban level. The land transaction data mainly comes from the manual collecting and sorting of China land market website (http://www.landchina.com (accessed on 5 December 2021)), which is the largest land transfer statistics platform in China. Meanwhile, the data collection time is subject to the signing time of the land transfer contract, which covers the period from 1 January 2010 to 31 December 2016 with a total of 535,387 pieces of land transaction data. The data mainly includes land transaction serial number, land parcel name, land location, planned use, transfer mode, transferred land area, transaction price, and other land-transfer-related information. Considering the availability and integrity of the data, the land transaction data of Hong Kong, Macao, Taiwan, and Tibet Autonomous Region are not included. The relevant data at the urban level comes from the manual sorting of the China Urban Statistical Yearbook and the China Urban Construction Statistical Yearbook over the years. At the same time, it also refers to the Statistical Yearbooks and annual bulletins of various provinces (cities, districts) over the years. The data related to carbon emissions are collected from China's carbon emissions database (https://www.ceads.net/data/ (accessed on 7 December 2021)). In order to ensure the accuracy of regression results, some missing data are supplemented by trend extrapolation and interpolation method; tail reduction processing function of Stata 15.0 is used to process the upper and lower 1% extreme-value sample data to make sure to eliminate the influence of outliers and reduce multicollinearity, along with decentralize the main variable data. Finally, based on the land transaction data set, taking the city and year as the key fields, we combined and matched the relevant data of land transactions, carbon emissions, and city level as a whole data set, 2037 pieces of balanced-panel data of 291 sample cities were obtained in the end.

3.3. Variable Measurements

3.3.1. Dependent Variables

The annual carbon dioxide emissions of cities are the main core variable of this paper, and different methods have great differences in the measurement of carbon emissions. Therefore, based on the research of relevant scholars and the availability, authority, and scientificity of data, this paper manually arranges the carbon emissions data of provinces and cities from the China carbon emission database (CEADS) [76].

3.3.2. Independent Variable

(1) Land Transaction Price

The calculation of land transaction price is more complex. This study manually collected the land transaction data of 291 prefecture-level and above cities in China from 2010 to 2016 through the China land market network. These data completely include the starting price, transaction price, and transaction area of each land transaction, as well as other information. In this paper, the annual land transaction area and price of the sample city are aggregated according to the land transaction purpose, and the ratio of the annual land transaction price to the successful land transaction area is calculated to obtain the average land price of the sample city in each year [77,78].

(2) Land Transaction Modes

China's first determination of the land transaction system in the form of local regulations can be traced back to 1986. Taking the land management system of the Hong Kong Special Administrative Region as a model, Shenzhen first reformed the land transaction system in the form of local regulations. Later, the State Council amended the land management law of the People's Republic of China in 1988, making the paid use system of land transactions legitimate [79]. Since entering the 21st century, the paid land use system has been continuously improved. The notice on strengthening the management of state-owned land assets issued in 2001 has fully mobilized the government's enthusiasm for paid land use rights, and the paid land transaction has entered an active period. State-owned land transaction methods mainly include agreement, bidding, auction, and listing. Because agreement transactions do not introduce a competition mechanism and the role of the market in land resource allocation is not fully reflected [80], this study only considers three land transactions: bidding, auction, and listing. In 2002, China formally established the market allocation system of state-owned land resources, promulgated and implemented the provisions on the transfer of state-owned land use rights by bidding, auction, and listing, which not only clearly stipulated the relevant land transaction methods, but also stipulated the criteria, procedures, scope, and legal responsibilities of the "bidding, auction, and listing" land transaction methods [81]. With the continuous advancement of the marketization process of land resource allocation, the scope of "bidding, auction, and listing" land transactions has become the mainstream of land transaction modes [47,82].

Combined with the research of this paper, we select the number of successful land transactions in each sample city each year by using the "bidding, auction, and listing" land transaction mode, and obtain the number of successful land transactions in the three ways of the city each year.

(3) Land Transfer Structure

Due to the large span of land transfer years, land transfer classifications and uses are different. In order to compare and analyze the land use classification in each period—unlike the previous study that used ArcGIS to analyze different land-use class features [83], this paper is based on the standard for classification and planning of urban land for construction (GB 50137-2011)—the main transferred land is divided into eight categories, namely residential land, industrial land, commercial land, land for roads and transportation facilities, land for public management and utilities, land for green spaces and squares, land for logistics and storage, and other special land, including religious land, land for military facilities, land for funerals, and other special land. The annual land transfer structure of eight categories from 2010 to 2016 is shown in Figure 3:

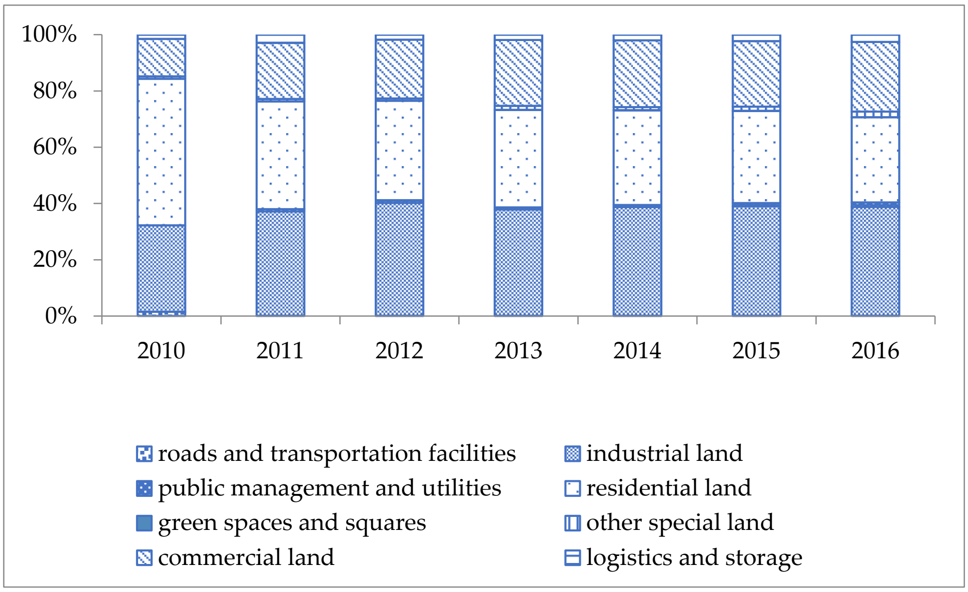


Figure 3. China's land transfer structure from 2010 to 2016.

It can be seen from Figure 3 that, in general, the amount of residential land, commercial land, and industrial land transferred from 2010 to 2016 account for a larger share and is relatively stable, which shows that the supply of these three types of land is relatively balanced every year. Meanwhile, the figure also shows that there are differences in the three types of land from 2010–2016. The proportion of residential land transfer is shrinking year by year, while the growth rate of industrial land transfer is slowing down year by year, and the number of industrial land transfer remains fluctuating and rising; the transfer of land for logistics and storage, land for roads and transportation facilities, and other special land also maintained a relatively stable growth rate, reflecting that China has invested a lot of land resources in infrastructure construction; although the proportion of green space and square land transfer is small, it maintains an upward trend, which is consistent with China's continuous attention to the policy guidance of green development. However, the proportion of public management and utility land transfer is too low, indicating that China's public management and utility resource allocation are unbalanced, and attention should be paid to the balanced development and construction of supply, environment, security, and other facilities.

Since the sum of the residential land, commercial land, and industrial land accounts for more than 90% of the total land, therefore, only these three types of land are considered in the analysis of land transfer structure and used as the measurement index in this paper, which are measured by the transfer proportion of residential, commercial, and industrial land in the total land transactions each year.

(4) Moderating Variables

In this study, we use two moderating variables in terms of the region and the time. In different regions of China, local governments with a higher degree of economic development may be more rational. Therefore, there are differences in attitudes towards carbon emissions. The annual per capita GDP of each city is used to measure the level of economic development [84] and test the moderating effect of the region. China has considered the requirements for greenhouse gas emission reduction since 2011—the policy pointed to the goal of achieving a 17% reduction in carbon dioxide emissions per unit of GDP by 2015 compared to 2010, in addition to vigorously carrying out pilot carbon emissions trading and continuously promoting the construction of a national carbon market system [85]. By 2013, China's CO_2 intensity had decreased by an average of 2.46% per year compared to 2000, with a cumulative decrease of 21.06% [86]. It can be expected that cities will reduce emissions more rationally after 2011. On the moderating effect of policy, time is a dummy variable coded as 1 if the year is 2011 and beyond; otherwise, 0.

3.3.3. Control Variables

Following previous research [87,88], we chose industrial structure, technical structure, manufacturing employment, sulfur dioxide emissions, green areas, government intervention, population density, and total urban GDP as the control variables of this paper. We took the natural log of all variables plus one, except three land transfer structure variables, to reduce the influence of the skewness issue. All of these variables are described in Table 1.

Table 1. List of variables and their measurement.

Variable Name	Measurement
Carbon dioxide emissions (CE)	Natural log of annual carbon dioxide emissions of cities
Land transaction price (Landprice)	Natural log of urban land transaction price per year divided by total land transaction area
Proportion of residential land (Residential)	Cities' number of urban residential land transactions per year divided by land transactions
Proportion of commercial land (Commercial)	Cities' number of commercial land transactions per year divided by land transactions
Proportion of industrial land (Industrial)	Cities' number of industrial land transactions per year divided by land transactions
Auction	Natural log of land transactions in cities by auction every year
Listing	Natural log of land transactions in cities by listing every year
Bidding	Natural log of land transactions in cities by bidding every year
Economic development level (Rgdp)	Natural log of cities' per capita GDP every year
Greenhouse gas emission reduction policy (Gerp)	1 if the year is after 2010; otherwise, 0
Industrial structure (Industry3)	Proportion of tertiary industry in urban GDP
Technical structure (Industry2)	Proportion of secondary industry in urban GDP
Manufacturing employment (Staff)	Natural log of urban annual manufacturing employment
Sulfur dioxide emissions (SE)	Natural log of annual sulfur dioxide emission of cities
Green area (Green)	Natural log of urban green space area
Government intervention (Gov)	Natural log of cities' total fiscal expenditure at the end of the year
Population density (Pop)	Natural log of population per unit area in urban administrative area

3.4. Models

According to the above analysis, this paper constructs the following models for empirical test.

$$CE_{it} = \alpha_0 + \alpha_1 Industry3_{it} + \alpha_2 Industry2_{it} + \alpha_3 Staff_{it} + \alpha_4 Green_{it} + \alpha_5 Gov_{it} + \alpha_6 SE_{it} + \alpha_7 Pop_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (1)$$

$$CE_{it} = \alpha_0 + \alpha_1 Landprice_{it} + \gamma Controls_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (2)$$

$$CE_{it} = \alpha_0 + \alpha_1 Actions_{it} + \alpha_2 Listing_{it} + \alpha_3 Bidding_{it} + \gamma Controls_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (3)$$

$$CE_{it} = \alpha_0 + \alpha_1 Residential_{it} + \alpha_2 Commercial_{it} + \alpha_3 Industrial_{it} + \gamma Controls_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (4)$$

$$CE_{it} = \alpha_0 + \alpha_1 Landprice_{it} + \alpha_2 Landprice_{it} \times Rgdp_{it}(Gerp_{it}) + \gamma Controls_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (5)$$

$$\begin{aligned} CE_{it} = {} & \alpha_0 + \alpha_1 Auction_{it} + \alpha_2 Listing_{it} + \alpha_3 Bidding_{it} + \alpha_4 Auction_{it} \times Rgdp_{it}(Gerp_{it}) \\ & + \alpha_5 Listing_{it} \times Rgdp_{it}(Gerp_{it}) + \alpha_6 Bidding_{it} \times Rgdp_{it}(Gerp_{it}) + \gamma Controls_{it} \\ & + \mu_i + \sigma_t + \varepsilon_{it} \end{aligned} \quad (6)$$

$$\begin{aligned} CE_{it} = {} & \alpha_0 + \alpha_1 Residential_{it} + \alpha_2 Commercial_{it} + \alpha_3 Industrial_{it} \\ & + \alpha_4 Residential_{it} \times Rgdp_{it}(Gerp_{it}) + \alpha_5 Commercial_{it} \times Rgdp_{it}(Gerp_{it}) \\ & + \alpha_6 Industrial_{it} \times Rgdp_{it}(Gerp_{it}) + \gamma Controls_{it} + \mu_i + \sigma_t + \varepsilon_{it} \end{aligned} \quad (7)$$

From Equations (1)–(7), subscript i represents each sample city, and t represents each year; Equation (1) represents the regression model of city carbon dioxide emissions (CE) and all control variables; all variables in Equations (2)–(7) have been described in detail in

Table 1 and will not be repeated here; μ_i and δ_i represent urban individual fixed effect and time fixed effect respectively, ε_{it} is the random interference term.

4. Empirical Results

4.1. Descriptive Analysis

Tables 2 and 3 present descriptive statistics and correlations for all variables used in this research. The average carbon dioxide emissions are 29.344, and the standard deviation is 25.188, indicating large differences across cities. All the correlations between the main explanatory variables are less than 0.5, and the maximum correlations between control variables are 0.826, which are high enough to suggest a multicollinearity problem. However, to ensure robust results, we conduct the variance inflation factor test. The maximum value is lower than the critical threshold value of 10, which indicates the empirical are not influenced by this cross-correlation [89].

Table 2. Descriptive statistics.

Variables	Mean	S. D.	Min	Max
1. CE	29.344	25.188	0.464	230.710
2. Landprice	5.453	1.286	0.000	12.084
3. Auction	3.300	1.423	0.693	7.096
4. Listing	4.976	0.966	0.693	7.340
5. Bidding	2.446	1.398	0.693	6.555
6. Residential	0.345	0.149	0.000	0.902
7. Commercial	0.227	0.122	0.000	1.000
8. Industrial	0.378	0.160	0.000	1.000
9. Rgdp	10.525	0.731	6.639	13.135
10. Gerp	0.857	0.350	0.000	1.000
11.Industry3	0.379	0.093	0.098	0.802
12.Industry2	0.494	0.103	0.150	0.898
13. Staff	6.110	4.675	0.058	14.771
14. SE	10.550	1.157	1.099	14.238
15. Green	8.143	1.059	3.219	11.881
16. Gov	13.647	1.042	11.028	18.050
17. Pop	5.745	0.905	1.800	7.882

Figure 4 gives the spatial locations of land transaction prices for the study area from 2010–2016. As can be seen from Figure 4, land transaction prices are higher in the east and central regions compared to the west, with prices in first-tier cities such as Shenzhen, Shanghai, Beijing, Guangzhou, and Hangzhou being higher compared to other cities, which are also consistent with the level of economic development of each prefecture-level city in China. Figure 5 gives the spatial locations of land transaction modes for the study area from 2010–2016, where (a) indicates the mode of auction, (b) indicates the mode of listing, and (c) indicates the mode of bidding. It can be seen from the figure that the sample cities that transfer land through auction mode are mainly concentrated in Shangrao, Weihai, Chongqing, and Qingdao; the sample cities that transfer land through the listing mode are mainly concentrated in Nantong, Suqian, Weifang, and Yancheng; the sample cities that transfer land through bidding mode are mainly centered at Liuan, Weifang, and Zhumadian. Figure 6 gives the spatial locations of land transfer structure for the study area from 2010–2016, where (a) indicates the land transfer structure of auction, (b) indicates the land transfer structure of listing, and (c) indicates the land transfer structure of bidding. Figure shows that among the three main types of land transfer structure, the sample cities with the highest proportion of residential land are mainly in Yongzhou, Baise, Yiyang, and Hengyang; the sample cities with the highest proportion of commercial land are mainly in Sanya, Yichun, and Liupanshui; the sample cities with the highest proportion of industrial land are mainly in Hefei, Taizhou, Zhangzhou, and Laiwu. The reasons for the differences in land transaction modes and land transfer structure are basically that there are differences in the land supply strategies and local development plans of local governments.

Table 3. Correlation matrix.

Variables	1	2	3	4	5	6	7	8	9
1. CE	1.000								
2. Landprice	0.093	1.000							
3. Auction	0.021	0.190	1.000						
4. Listing	0.370	0.100	0.177	1.000					
5. Bidding	0.008	−0.104	0.097	0.043	1.000				
6. Residential	−0.170	0.149	0.181	−0.011	−0.089	1.000			
7.Commercial	0.013	−0.072	−0.088	−0.109	−0.048	−0.320	1.000		
8. Industrial	0.153	−0.064	−0.074	0.118	0.141	−0.440	−0.470	1.000	
9. Rgdp	0.469	0.053	−0.096	0.117	−0.097	−0.375	0.131	0.224	1.000
10. Gerp	0.045	−0.024	0.104	0.145	−0.049	−0.082	0.118	−0.015	0.177
11. Industry3	0.343	0.119	−0.116	0.015	−0.128	−0.161	0.167	−0.014	0.332
12. Industry2	0.010	−0.061	0.034	0.035	0.051	−0.093	−0.122	0.200	0.253
13. Staff	0.162	−0.018	0.106	0.194	−0.107	−0.180	0.113	0.050	0.319
14. SE	0.437	0.040	0.006	0.205	0.035	0.016	−0.082	0.071	0.208
15. Green	0.591	0.125	0.049	0.194	0.005	−0.222	−0.060	0.250	0.644
16. Gov	0.612	0.159	0.032	0.181	−0.104	−0.232	−0.011	0.216	0.656
17. Pop	0.261	0.196	0.149	0.037	0.022	−0.042	−0.248	0.250	0.160
Variables	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
10. Gerp	1.000								
11. Industry3	0.098	1.000							
12. Industry2	−0.060	−0.676	1.000						
13. Staff	0.352	0.342	−0.172	1.000					
14. SE	−0.018	−0.089	0.351	−0.115	1.000				
15. Green	0.068	0.449	0.033	0.272	0.237	1.000			
16. Gov	0.180	0.536	−0.063	0.379	0.161	0.826	1.000		
17. Pop	0.004	0.180	0.106	0.149	0.130	0.452	0.512	1.000	

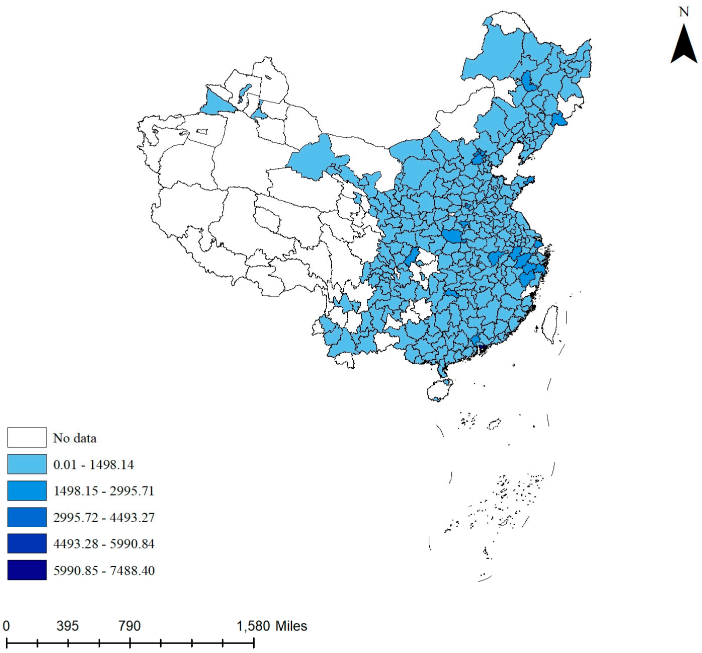
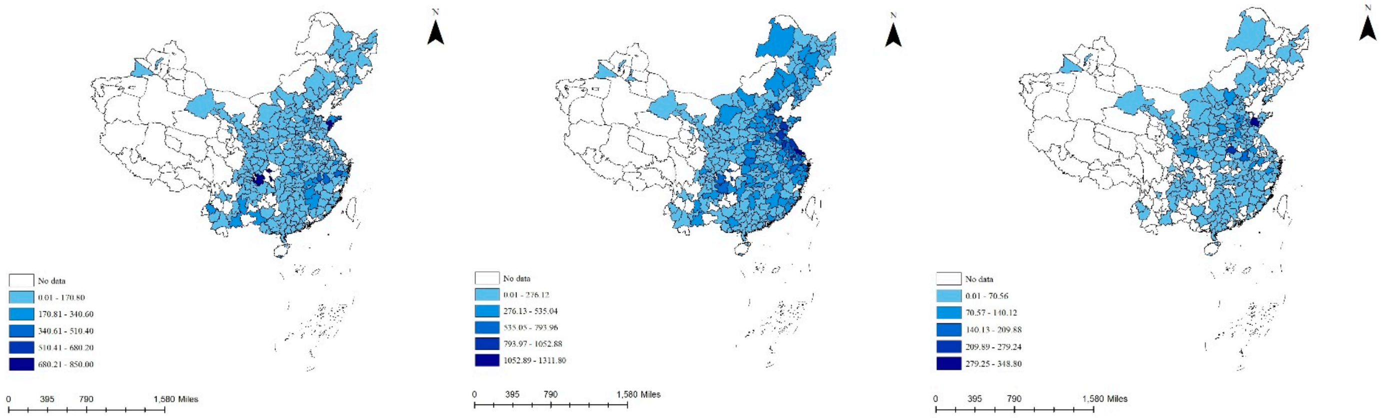
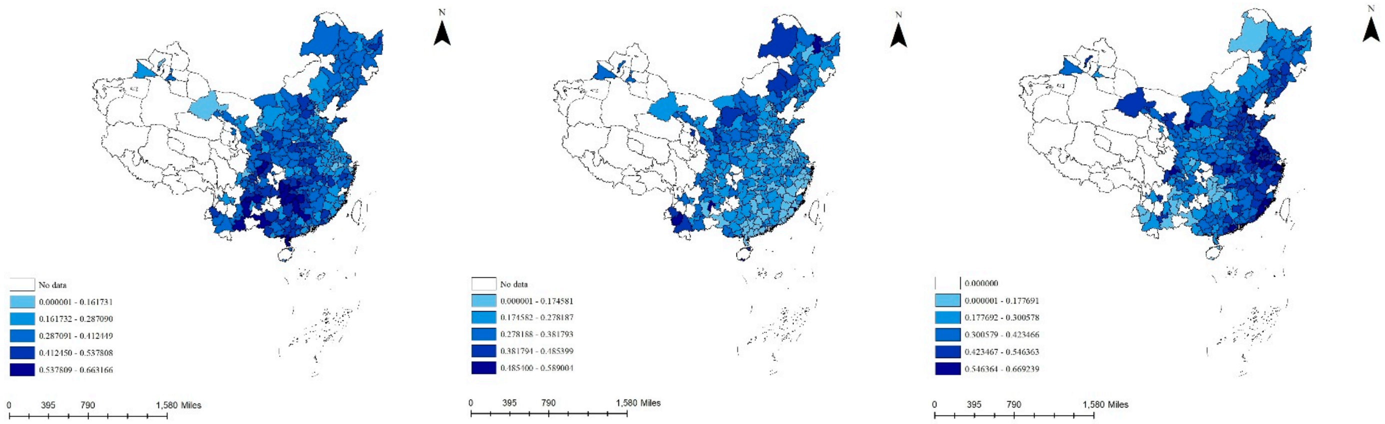


Figure 4. The spatial distribution of land transaction prices in the study area from 2010–2016.



(**a**) (**b**) (**c**)

Figure 5. The spatial distribution of land transaction modes in the study area from 2010–2016. (**a**) The mode of auctions. (**b**) The mode of listing. (**c**) The mode of bidding.



(**a**) (**b**) (**c**)

Figure 6. The spatial distribution of land transfer structure in the study area from 2010–2016. (**a**) The transfer structure of residential land. (**b**) The transfer structure of commercial land. (**c**) The transfer structure of industrial land.

4.2. Regression Results

In order to ensure the accuracy of empirical results, the correct regression model should be selected before empirical regression analysis. Through the test of individual effect and time effect, we determined that the fixed effect and random effect model is better than the mixed ordinary least squares (OLS) model. Then, the Hausman test was carried out to get the result with p value of 0, indicating that the original hypothesis should be fully rejected. Therefore, this paper selects the fixed-effect model for empirical regression (regression results can be requested from the authors).

4.2.1. Land Transaction Price and Carbon Emissions

We use Equation (1) to regress all control variables and dependent variables—the regression results are shown in model (1) in Table 4. It can be seen that the regression coefficients of technical structure (Industry2), sulfur dioxide emissions (SE), green area (Green), government intervention (Gov), and population density (Pop) with the dependent variables have passed the test at the significance level of 1%, and the directions are positive, while the regression coefficients of industrial structure (Industry3), manufacturing employment (Staff) have not passed the significance test, and the directions are consistent with the expectation. In conclusion, these variables should be controlled.

Table 4. Regression results of land transaction price and urban carbon emissions.

Variables	Model (1)	Model (2)
Landprice		−0.123 **
		(−2.233)
Industry3	11.164	−3.569
	(1.525)	(−0.525)
Industry2	16.295 ***	3.075
	(2.788)	(0.582)
Staff	−0.005	0.132
	(−0.226)	(0.585)
SE	0.534 ***	0.227 **
	(4.558)	(1.974)
Green	1.081 ***	0.207
	(3.889)	(0.889)
Gov	2.217 ***	−0.266
	(8.331)	(−0.984)
Pop	4.261 ***	2.657
	(3.981)	(1.386)
Constant	−51.872 ***	10.332
	(−6.919)	(0.887)
Year	NO	YES
City	NO	YES
Observations	2037	2037
R-squared	0.291	0.315

t-values are enclosed in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In order to verify the theoretical Hypothesis 1, we use Equation (2) for empirical regression, and the results are shown in model (2) in Table 4. The regression coefficient between land price and urban carbon dioxide emission (CE) is negative and significant ($\alpha = -0.123$, $p < 5\%$), indicating that land transaction price can significantly reduce urban carbon dioxide emission. The higher the land transaction price is, the lower the number of land transactions can be, the urban expansion can be restrained to some extent, and then the urban carbon dioxide emission can be effectively reduced. The theoretical hypothesis 1 has been proved.

4.2.2. Land Transaction Modes and Carbon Emissions

In order to explore the impact of different land transaction modes on urban carbon emissions and prove the theoretical hypothesis 2, we use Equation (3) to empirically test the relationship among three different land transaction modes and the dependent variables, respectively, as shown in Table 5. Model (3) reports the regression results between the number of successful land transactions by auctions and urban carbon emissions, the coefficient is significantly negative ($\alpha = -0.210$, $p < 1\%$). It shows that the more successful land transactions by auctions, the more urban carbon dioxide emissions can be reduced. Model (4) reports the regression results between the number of listed land transactions and urban carbon emissions; the coefficient is also significantly negative ($\alpha = -0.618$, $p < 1\%$), indicating that the more land traded by listing can also significantly inhibit urban carbon dioxide emissions. Model (5) reports the regression results between the number of land traded by bidding and urban carbon emissions. It can be seen that its correlation coefficient is significantly negative ($\alpha = -0.296$, $p < 10\%$); however, the inhibitory effect is not as strong as the first two land transaction modes, which may be due to the fact that the bidding method is the transfer method with the lowest land marketization level among the three methods of "bidding, auction, and listing", which is vulnerable to the influence of "black box operation". Moreover, the types of land transactions made by bidding are mainly the land areas with specific social and public welfare construction conditions and strictly limited land use, and only a few people have the intention to trade. Therefore, the more land transactions by means of bidding may not have a strong relationship with urban carbon dioxide emissions. Hypothesis 2 is supported.

Table 5. Regression results of land transaction modes and urban carbon emissions.

Variables	Model (3)	Model (4)	Model (5)
Auction	−0.210 *** (−2.927)		
Listing		−0.618 *** (−5.257)	
Bidding			−0.296 * (−1.904)
Industry3	−5.132 (−0.768)	−3.952 (−0.581)	−13.745 (−0.997)
Industry2	−0.835 (−0.160)	3.517 (0.669)	−1.133 (−0.101)
Staff	0.747 *** (3.217)	0.235 (1.043)	0.523 (1.108)
SE	0.204 * (1.704)	0.172 (1.497)	0.738 *** (3.269)
Green	0.204 * (1.704)	0.229 (0.990)	1.005 (1.619)
Gov	−0.536 ** (−2.153)	−0.253 (−0.942)	−0.261 (−0.488)
Pop	4.427 ** (2.410)	3.073 (1.602)	1.774 (0.554)
Constant	4.117 (0.364)	10.801 (0.928)	13.569 (0.595)
Year	YES	YES	YES
City	YES	YES	YES
Observations	2037	2037	2037
R-squared	0.442	0.327	0.350

t-values are enclosed in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2.3. Land Transfer Structure and Carbon Emissions

Furthermore, we use Equation (4) to conduct regression analysis on the relationship between urban annual land transfer structure and urban carbon emissions—the results are shown in Table 6. Model (6), model (7), and model (8) report the regression results between the proportion of residential land, commercial land, industrial land, and urban carbon emissions, respectively. It can be seen that both the coefficients of residential land and industrial land for the urban carbon emissions are significant, but the correlation directions are opposite ($\alpha = -2.005$, $p < 1\%$; $\alpha = 1.691$, $p < 1\%$), which show that the higher the successful proportion of high-greening-rate residential land, the more effective it is at reducing urban carbon emissions, while the high proportion of industrial land transaction leads to the synchronous growth of urban carbon emissions. Those are consistent with our theoretical hypothesis 3. The correlation coefficient between the proportion of commercial land transactions and urban carbon emissions failed to pass the test. This may be due to the strengthening of public awareness of green environmental protection in recent years and the increasing greening rate of commercial land. To sum up, two parts of hypothesis 3 are supported.

Table 6. Regression results of land transfer structure and urban carbon emissions.

Variables	Model (6)	Model (7)	Model (8)
Residential	−2.005 *** (−3.224)		
Commercial		0.291 (0.405)	
Industrial			1.691 *** (2.957)
Industry3	−1.551 (−0.228)	−3.479 (−0.511)	−2.359 (−0.347)
Industry2	4.694 (0.886)	3.113 (0.588)	4.036 (0.764)
Staff	0.141 (0.627)	0.122 (0.540)	0.100 (0.447)
SE	0.248 ** (2.154)	0.231 ** (2.005)	0.243 ** (2.117)
Green	0.187 (0.807)	0.199 (0.852)	0.202 (0.871)
Gov	−0.294 (−1.088)	−0.269 (−0.993)	−0.276 (−1.023)
Pop	2.915 (1.521)	2.527 (1.316)	2.810 (1.466)
Constant	8.334 (0.715)	11.043 (0.946)	7.937 (0.679)
Year	YES	YES	YES
City	YES	YES	YES
Observations	2037	2037	2037
R-squared	0.317	0.312	0.317

t-values are enclosed in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2.4. The Moderation of Economic Development

We proposed hypothesis 4a, hypothesis 4b, and hypothesis 4c to discuss the influence of regional conditions and the level of economic development (Rgdp), towards the main effect. The regression coefficients are represented in Table 7. Equation (5) is used to test the moderating effect in the relationship between land transaction price and urban carbon emissions—the result is shown in model (9). The coefficient of the interaction of Rgdp× Landprice is significantly negative ($\alpha = -0.358$, $p < 1\%$), which indicates that the level of economic development plays a negative moderating role. The higher the level of economic development, the stronger the inhibitory effect of land transaction price on carbon dioxide emissions. Hence, hypothesis 4a is supported at the relative higher level of statistical significance.

Equation (6) is used to test the relationship between land transaction modes and urban carbon emissions under the moderation of the level of economic development, the results are shown in model (10), model (11), and model (12). All the coefficients of the interaction of land transaction modes and urban carbon emissions are significant and negative ($\alpha = -0.449$, $p < 1\%$; $\alpha = -0.225$, $p < 5\%$; $\alpha = -0.297$, $p < 10\%$). However, the interaction of land transactions by bidding and the level of economic development (Rgdp× Bidding) is under the relative lower level of statistical significance. The results shows that the level of economic development has a moderating role in the relationship of all the types of land transaction modes and urban carbon emissions, but there are obvious differences among those moderating effects; the lowest level of statistical significance is the moderating effect of the relationship between land transaction by bidding and carbon emissions, supporting Hypothesis 4b.

Table 7. Regression results of moderating effect of Rgdp.

Variables	Model (9)	Model (10)	Model (11)	Model (12)	Model (13)	Model (14)
Landprice	−0.177 *** (−3.176)					
Auction		−0.182 ** (−2.557)				
Listing			−0.544 *** (−4.450)			
Bidding				−0.322 ** (−2.063)		
Residential					−2.154 *** (−3.445)	
Industrial						1.536 *** (2.680)
Rgdp× Landprice	−0.358 *** (−4.872)					
Rgdp× Auction		−0.449 *** (−5.619)				
Rgdp× Listing			−0.225 ** (−2.214)			
Rgdp× Bidding				−0.297 * (−1.756)		
Rgdp× Residential					−1.526 ** (−2.119)	
Rgdp× Industrial						1.868 *** (2.874)
Rgdp	0.003 (0.014)	1.585 *** (4.412)	1.047 ** (2.009)	0.884 (1.545)	0.583 (1.528)	−0.645 * (−1.902)
Constant	5.911 (0.509)	3.703 (0.331)	9.595 (0.823)	10.967 (0.480)	8.813 (0.755)	7.300 (0.625)
Controls	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
City	YES	YES	YES	YES	YES	YES
Observations	2037	2037	2037	2037	2037	2037
R-squared	0.326	0.460	0.329	0.354	0.320	0.321

t-values are enclosed in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Because the main effect of the proportion of commercial land and carbon emissions is not significant, the moderating effect test is omitted when using Equation (7) to test the moderating effect of the economic development level on land transfer structure and carbon emissions. The coefficients of the interaction of proportion of residential land and the level of economic development (Rgdp× Residential) in model (13) are significantly negative ($\alpha = -1.526$, $p < 5\%$), indicating that the level of economic development has a negative moderating effect. Because the main effect is also negative, the economic development level would increase the negative effect of the main effect. However, the other coefficient of the interaction of proportion of industrial land, and the level of economic development (Rgdp× Industrial) in model (14) is significantly positive ($\alpha = 1.868$, $p < 1\%$), which shows that the economic development level increases the main effect, and this is not what we expected. It may be that the local government is not rational enough and the relevant infrastructure has not been further improved. Hypothesis 4c is partly supported.

4.2.5. The Moderation of Emission Reduction Policy

Similarly, in Table 8, we use Equations (5)–(7) to discuss the influence of policy condition, greenhouse gas emission reduction policy in 2011 (Gerp), towards the main effect. Equation (5) is used to test the moderating effect of emission reduction policy in the relationship between land transaction price and carbon emission. The result in model (15) shows that the coefficient of the interaction of land transaction price and emission reduction policy (Gerp× Landprice) is significantly negative ($\alpha = -0.348$, $p < 1\%$). This indicates that emission reduction policy enhances the negative relationship between land transaction price and carbon emissions, so the government can thoroughly implement the greenhouse gas emission reduction policy, which makes the carbon emissions more sensitive to the land transaction price, and the land transaction price has a stronger inhibitory effect on the carbon emissions. Hypothesis 5a is supported.

Table 8. Regression results of the moderating effect of Gerp.

Variables	Model (15)	Model (16)	Model (17)	Model (18)	Model (19)	Model (20)
Landprice	−0.178 *** (−3.139)					
Auction		−0.210 *** (−2.923)				
Listing			−0.510 *** (−4.404)			
Bidding				−0.289 * (−1.852)		
Residential					−2.068 *** (−3.305)	
Industrial						1.666 *** (2.891)
Gerp× Landprice	−0.348 *** (−3.728)					
Gerp× Auction		−0.075 (−0.740)				
Gerp× Listing			1.106 *** (7.694)			
Gerp× Bidding				−0.129 (−0.683)		
Gerp× Residential					−0.857 (−0.924)	
Gerp× Industrial						−0.320 (−0.375)
Gerp	1.663 (0.800)	−3.718 * (−1.723)	−3.317 (−1.568)	−2.265 (−0.512)	1.776 (0.837)	1.976 (0.944)
Constant	9.442 (0.812)	0.492 (0.043)	10.378 (0.910)	10.038 (0.428)	10.232 (0.875)	9.343 (0.798)
Controls	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
City	YES	YES	YES	YES	YES	YES
Observations	2037	2037	2037	2037	2037	2037
R-squared	0.322	0.443	0.354	0.351	0.318	0.317

t-values are enclosed in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

From the results of moderating effects between land transaction modes and urban carbon emissions in model (16), model (17), and model (18), only the coefficient of the interaction of land transaction by listing and carbon emissions (Gerp× Listing) is significantly positive ($\alpha = 1.106$, $p < 1\%$), in the opposite direction of our expected moderating effect. What's more, the other two interactions' coefficients do not pass the relative lower level of statistical significance, suggesting that Hypothesis 5b is not supported. It takes a long time to implement the greenhouse gas emission reduction policy, and China's provisions on land transaction mode are gradually improving, and the time for the effectiveness of emission reduction policy will lag accordingly. Therefore, the moderating effect of emission reduction policy on land transaction mode and carbon emission will be biased. Moreover, the coefficient of the interactions of land traded by auction, bidding, and carbon emissions is negative, which also shows that the emission reduction policy has a negative moderating trend.

As mentioned above, we also omit the moderating effect test of emission reduction policy between the proportion of commercial land and carbon emissions and use Equation (7) to test whether the moderating effect exists in the relationship of the other two land transfer structures and urban carbon emissions. As we can see in model (19) and model (20), both the coefficients of the interaction are not significant, which means that emissions reduction policy does not play a moderating role. In other words, the emission reduction policy does not play a moderating role between land transfer structure and urban carbon emissions, so Hypothesis 5c is not verified. The supply of land is less affected by the emission reduction policy, and the effect is limited to a certain extent. In the follow-up practice, China proposed the dual carbon goal of carbon peak and carbon neutralization, which further accelerated the pace of reducing carbon emissions in combination with a series of existing relevant emission reduction policies.

4.3. Robustness Test

In order to ensure the reliability and accuracy of the empirical results, we performed a robustness test for the main results by changing the sample range. Referring to previous studies [90,91], since cities above prefecture level and provincial capital cities have greater resource advantages and infrastructure advantages than other cities, we conducted regression after excluding 35 sample cities of provincial capital cities and cities above prefecture-level cities. Through regression, excepting for the difference of coefficients, the rest are consistent with the previous analysis, which show that the empirical results are robust. Due to the length of the article, the robustness test results are not presented (regression results can be requested from the authors).

5. Conclusions and Discussion

5.1. Conclusions

This paper provides a moderation model to explore the relationship between land transactions and urban carbon emissions and how economic development level and emission reduction policy moderate the relationship between land transactions and urban carbon emissions. Through an analysis of 291 prefecture-level and above cities in China from 2010–2016, we find that there is variability in the impact of the three dimensions of land trading on carbon emissions, and that both economic development level and emission reduction policy play a moderating role in the relationship between land transactions and urban carbon emissions. The moderation effect of economic development level is better than that of emissions reduction policy.

5.2. Discussion

To be more specific, our empirical results can be divided into two steps. In the first step of this casual chain, in which land transactions affect urban carbon emissions, our empirical results clearly show that land transaction price and three types of land transaction modes can inhibit urban carbon emission. However, in terms of land transfer structure, the proportion of residential land transactions can inhibit urban carbon emission, while the relationship between the proportion of industrial land transactions and carbon emission is significantly positive. The results of the second step reveal that economic development level can significantly enhance the negative correlation between land transaction price, three land transaction modes, the proportion of residential land transaction, and carbon emissions. The emission reduction policy also plays a negative moderating role between land transaction price and carbon emissions, and the moderating effect on other relationships is not significant as expected.

Moreover, the findings can offer practical implications for managers and policy makers. First, the government should take improving the quality of land supply as the grasp to achieve the dual-carbon goal. On the one hand, it should implement the "Opinions on Building a More Perfect System of Factor Market Configuration" issued in March 2020 as far as possible, continue to promote the reform of land elements market, gradually dilute the monopoly ability of land administrative resources by cultivating more types of primary market entities, and build clear property rights and interests protections and an effective pattern of land market competition; on the other hand, the land use planning should be arranged in an overall way, and the differentiated land supply mode should be implemented, especially the expansion of land transaction forms and make better use of land market price mechanism. For the exit mechanism of traditional industrial land, price guidance and cost inversion are also needed. The market and administration work together to recycle land resources in an orderly way.

Second, the government should provide more favorable conditions for carbon emission reduction through macro-control and market mechanisms, give full play to the leading role of high economic level cities in carbon emission reduction, formulate carbon emission reduction targets based on local conditions, and innovate collaborative emission reduction ideas, so as to promote emission reduction policies from "point" to "surface". At the same time, according to the carrying capacity of resources and environment, promote the rational allocation of land resource elements and realize the spatial classified management of low-carbon resources.

5.3. Limitations and Future Considerations

Although this paper provides a more detailed empirical analysis of the relationship between land transactions and carbon emissions, there are still some limitations that could be further improved in the future. First, the land transaction data used in this study are at the prefectural level and above, and although they are complementary to traditional studies using country or provincial level data, district and county level land transaction data are also an important part of the sample that are not addressed in this paper. This is due to the current incomplete disclosure of data on district and county level land transactions on the China land market website and serious data deficiencies. In order to ensure the consistency of the data and the accuracy of the subsequent empirical analysis, only land transaction data at the prefecture level city and above are considered in this paper. When land transaction data at district and county level become available in the future, the analysis sample can be further expanded for a more systematic analysis. Furthermore, in the robustness test, we use the method of removing the sample data of prefecture level above cities to rerun the empirical regression, and the empirical results show that it passes the robustness test. Then, whether there is any difference in the mechanism of action between land transactions and carbon emissions in prefecture level cities and cities above prefecture level cities is an area that can be explored in depth subsequently. Finally, this paper focuses on the impact of land transactions on carbon emissions in a specific Chinese environment. Since land transactions policies differ from country to country, the conclusions obtained in this paper may be more suitable for developing countries with the same background as China, and the research sample can be extended to foreign developed countries in the future to further explore the relationship between land transactions and carbon emissions based on different political systems and policy differences.

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