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Examining the Impact of Real Estate Development on Carbon Emissions Using Differential Generalized Method of Moments and Dynamic Panel Threshold Model

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Abstract: The development of the real estate industry inevitably consumes large amounts of fossil energy and makes great contributions to China's carbon emissions. However, very few research studies have explored the intrinsic link and influence mechanisms between the rapidly growing real estate sector and carbon emissions in China. Hence, this study investigated the impact of real estate development on carbon emissions using a differential generalized method of moments and dynamic panel threshold models. The empirical results show that: (1) There is a non-linear relationship between real estate development and China's carbon emissions, first promoting and then inhibiting them with the increasing level of real estate development, but it will take a long time to reach the latter stage in the future; (2) The threshold effect of economic development levels on carbon emissions was identified with a threshold value of 9.904, and the positive impact of real estate development on China's carbon emissions is more significant in economically backward areas; (3) The threshold effect of population sizes on carbon emissions was identified with a threshold value of 7.839, and in areas with larger populations, the positive impact of real estate development on China's carbon emissions is more significant. The findings above extend the carbon emission literature by clarifying the threshold role of the economic development level and population size between real estate development and carbon emissions. Furthermore, the findings of this study are instructive for China to formulate energy-saving and emission-reduction policies according to local conditions and will ultimately contribute to achieving the goal of "carbon peaking" and "carbon neutrality".

Keywords: real estate development; carbon emissions; differential GMM; dynamic panel threshold model

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1. Introduction

After the implementation of the housing allocation mechanism reformation in 1998, China's real estate industry had been developing at a rapid pace and its proportion of the gross domestic product in the national economy has increased year by year. In 2003, China's real estate development investment amounted to RMB 101.53 billion, accounting for only 7.39% of the gross domestic product [1]; while by 2019, China's real estate development investment had reached RMB 13,219.426 billion, accounting for 13.40% of the gross domestic product [2]. The real estate sector has gradually turned into the backbone of China's macroeconomic growth. However, the high rate of economic growth and industrial development inevitably results in considerable energy consumption, causing China's total carbon emissions to dramatically increase over the years. In 2019, China's total carbon emissions came to 9.81 billion tons, contributing 28.55% to the global carbon emissions, resulting in China now being the most significant carbon emitter in the world [3]. The real estate sector's contribution to the production of such a large amount of carbon emissions cannot be ignored. While promoting the building of the country's infrastructure and the economic growth of the country, the real estate industry has encouraged the flourishing of its associated industries as well (the transport industry, construction industry, and construction materials industry); the operation of these industries consumes large amounts of fuel and releases a large quantity of carbon emissions [4,5]. As the real estate sector has been shown in previous studies to play a key role in controlling energy consumption and CO_2 emissions in China [6], and the total carbon emissions are directly proportional to the growth of the real estate industry, China's carbon-reduction policy should consider real estate to be a key industry; thus, the mechanism of influence real estate development has on China's carbon emissions deserves in-depth study.

With the growing awareness of environmental protection, studies on the variables that influence carbon emissions have gradually begun to attract the attention of researchers worldwide. However, most of the studies focus on energy prices [7], industry structure [8], technological innovation [9], etc. Less attention has been paid to the real estate industry, which undoubtedly is a significant energy consumer [6,10]. The production of the real estate industry is accompanied by many procedures, such as the construction of infrastructure and the preparation and transportation of materials, which consume large amounts of energy and release carbon dioxide [5]. In addition, the operation and maintenance phase of real estate buildings also consumes large amounts of electricity, heat, and fossil energy, and generates carbon emissions that cannot be underestimated [5]. In this way, guiding the sustainability and health of the real estate sector plays a crucial role in ensuring the effective implementation of China's energy-conservation and emission-cutting policy measures. Existing studies are not deep enough; most of these studies are devoted to the direct measurement of carbon emissions and efficiency in construction and related sectors [10,11], and the potential mechanisms of how real estate development influences carbon emissions have not been examined in sufficient detail. However, it is necessary to understand the potential mechanisms of real estate development's impact on China's carbon emissions to find new ways to achieve real estate sector decarbonizing and control national carbon emissions.

Previous research has shown that the influence of various factors on carbon emissions are largely dependent on the regional economic level [12]; for example, some scholars have found that in economically undeveloped regions, technological progress will have a positive impact on carbon emission intensity, but in economically developed regions, technological progress will have a negative impact on carbon emission intensity [13]. The role of population size as a threshold for carbon emissions and its antecedents have also been confirmed, with numerous studies finding that the positive influence of energy consumption on carbon emissions is more pronounced in regions with higher population size [14,15]. In this case, what role do regional economic level and population size play in regulating the impact of real estate development on carbon emissions? The answers to these issues can be a helpful reference for government departments establishing effective energy-saving and emission-reduction policies and help to achieve the national goals of "carbon peaking" and "carbon neutrality" while maintaining high-quality economic development.

Thus, the objective of this paper is to clarify the relationship between real estate development and carbon emissions in China and to examine the possible threshold effects of economic development level and population size. To achieve this, a differential generalized moment estimation method (DIF-GMM) was used, as proposed by Arellano and Bond in 1991 to effectively address the endogeneity of panel data in order to obtain more robust estimation results [16]. The dynamic panel threshold regression models were established using balanced panel data from 30 provinces and municipalities directly under the Central Government and autonomous regions of China from 2003 to 2019. In its theoretical aspect, this study fills a current research gap and constructs a basic framework of the possible relationship between real estate development and carbon emissions and its intrinsic influence mechanism using GDP and population size as threshold variables. In practice, by clarifying the impact of real estate development on carbon emissions, this study helps to provide a theoretical basis and practical guidelines for achieving the goals of " carbon peaking " and "carbon neutrality".

2. Literature Review and Research Hypotheses

Previous studies have verified that carbon emissions are affected by various factors such as economic growth [17], energy consumption [18], changes in industrial structure [19], and urbanization rates and population size [12,20]. Of these factors, economic growth and population size have been shown to have a significant impact on carbon emissions. Researchers in various countries and regions have carried out numerous theoretical analyses and empirical tests using various layers of data and different models. Lu (2018) examined the positive effect of GDP on the growth of CO_2 emissions using panel data for 12 Asian countries spanning 20 years [17]. Zheng, et al. (2021) verified the single threshold effect of the level of economic development on China's carbon emissions intensity based on a threshold panel model, it is verified that the degree and effect of technological progress on carbon emission intensity varies in regions with different levels of economic development [13]. Chen, et al. (2019) constructed a PSTR model to analyze that environmental regulation and industrial structure have significant non-linearities in terms of CO_2 emissions in China [19]. In addition, the impact of urbanization rates has been demonstrated with studies showing that in some cities and regions, rising urbanization rates increase the utilization of public infrastructure and the efficiency of energy use, contributing to energy saving and emission reduction. Al-mulali et al. (2012) used fully modified ordinary least squares (FMOLS) to examine the long-term relationship between urbanization rates, energy consumption, and carbon dioxide emissions in seven regions around the world and a long-term negative relationship between urbanization rates and carbon emissions was found in some countries [21]. However, in other cities and regions, rising urbanization rates can instead increase carbon emissions, this is because the effects of urbanization rates on carbon emissions also depend on the level of urbanization. Dong, et al. (2019) used a threshold regression model to examine the double-threshold effect of urbanization on carbon emissions, and the effect tends to be firstly inhibited and then promoted as the level of urbanization continues to increase [20].

As a leading driver of economic growth, the real estate industry has been receiving close attention from academics, but there is not much literature linking it to carbon emissions. The existing studies have yielded rich results on the interrelationship between real estate development and population size [22], economic growth [23], urbanization rates [24], etc. The study of Tan, et al. (2012) showed that population size is an important factor affecting housing prices in Jilin province and an increase in population stimulates housing demand in the short term, thus accelerating the development of the real estate market [22]. Kong, et al. (2016) confirmed the positive impact of real estate investment on China's economic growth at both national and regional levels using a dynamic panel data model [23]. Liu, et al. (2018) validated that urbanization can increase real estate investment in parts of China by increasing housing demand through population clustering [24]. These studies showed that several common factors influence both real estate development and carbon emissions, and that the former may also have a significant impact on the growth of carbon emissions. There have been studies linking real estate development and carbon emissions to explore their impact pathways. Vimpari (2021) examined the relationship between energy subsidies and house prices in Finland, and found that residents of urban areas with high house prices were more likely to invest in energy efficiency without subsidies compared to residents of urban areas with low house prices [25]. Fan et al. (2019) explored the mechanism of mutual promotion between urbanization and real estate investment and the positive direct impact and spillover effects of their interaction on carbon emissions [4]. However, the existing literature on the mechanisms of the impact of real estate development on carbon emissions in China is not sufficient and does not consider possible threshold effects. The relationship between real estate development and economic level and population size, and the relationship between carbon emissions and economic level and population size, has been largely established. However, the relationship between real estate development and carbon emissions needs further research.

Figure 1 depicts the trend of China's carbon emissions over time from 2003 to 2019, which can be divided into two stages: the "climbing period" and the "stable period". China's carbon emissions rose rapidly in 2003–2012, from 4532.15 million tons in 2003 to 9001.26 million tons in 2012, with an average annual growth rate of 9.86%. Since 2013, China's carbon emissions have entered the phase of steady rise, with an average annual growth rate of only 0.87% between 2013 and 2019, which is not only related to the slowdown of China's economic growth but also cannot be separated from the effective implementation of the country's policies regarding energy saving and emission reduction. Figure 2 illustrates the trend of China's real estate development investment over time from 2003-2019; the development of the real estate sector has been a huge challenge to environment protection and energy consumption while driving China's economic growth. Given that the growth curve of real estate development investment in China is largely consistent with carbon emissions, there seems to be a specific correlation between the development of the real estate sector and the trend of carbon emission growth in China.

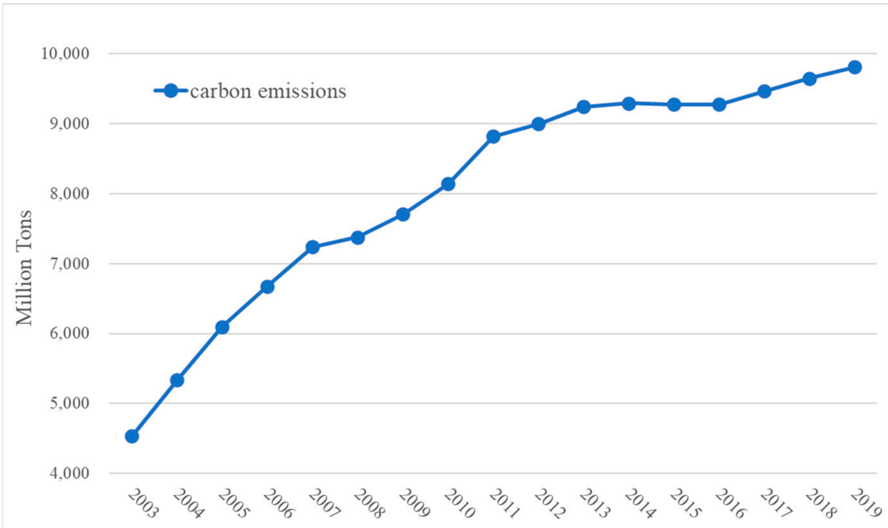

Figure 1. Trends in China's carbon emissions from 2003–2019.

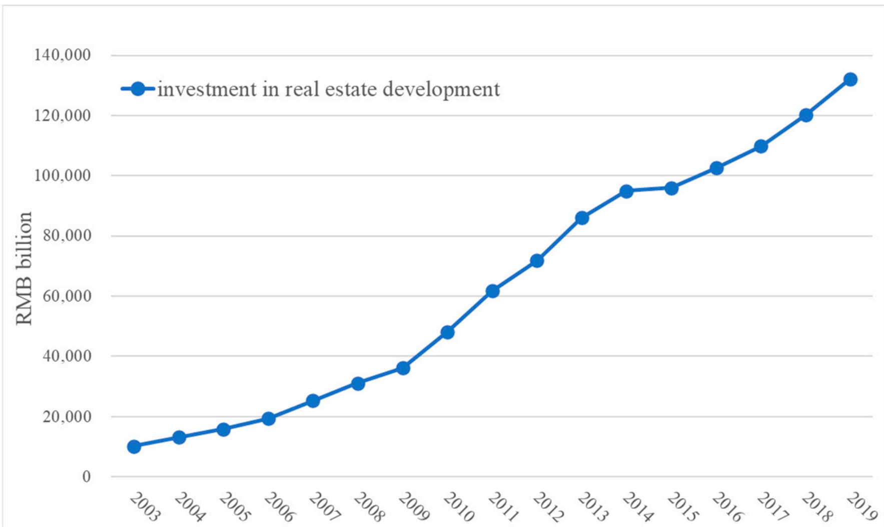

Figure 2. Trends in China's real estate development investment from 2003–2019.

The present study divides the impact of China's real estate sector on carbon emissions into three pathways, as shown in Figure 3: (1) The process of real estate production and construction is accompanied by the operation of much equipment for building construction and the consumption of large quantities of building materials, mainly steel and cement, both of which activities release large amounts of carbon dioxide. (2) During the operation of the real estate buildings, a large amount of fossil energy is consumed in the operation of the warming and heating systems as well as a large amount of carbon dioxide being released from the electricity and heat consumed in daily life. (3) The development of real estate will contribute to the booming development of its related upstream and downstream chains, such as the building-material manufacturing industry and the transportation industry. The operation of these industries also requires a large amount of energy consumption, leading to further increases in carbon emissions.

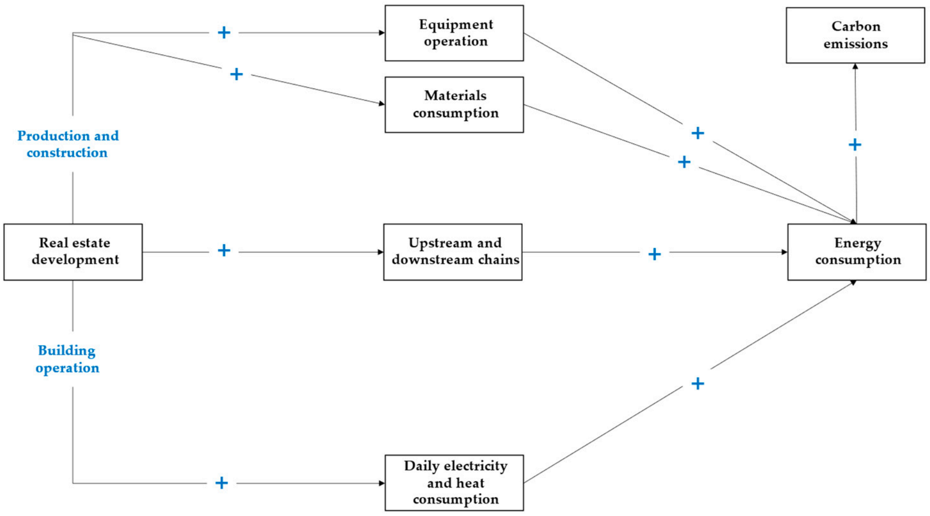

Figure 3. The impact pathways of real estate development on carbon emissions.

Given this, Hypothesis 1 was proposed:

Hypothesis 1 (H1). *Real estate development positively contributes to carbon emissions.*

This study also considers the nonlinear relationship between real estate development and carbon emissions, with the possible threshold effect of the level of economic development. Firstly, per capita income levels are higher in economically developed areas, and people's income levels are often proportional to their level of education [26,27]. Economically developed regions tend to attract more highly educated people [26], who are also more aware of energy conservation and environmental protection [28]. Secondly, governments in economically prosperous regions have stricter control over the real estate market, as evidenced by the fact that real estate companies are subject to more regulatory restrictions on the development of a project, and economic support is an important influence on the development of green buildings [29,30]. A large number of energy-saving and emission-reduction regulations and the development of green buildings mitigate the impact of real estate development on carbon emissions in economically developed regions, while in economically underdeveloped areas, the residents do not have a strong awareness of environmental protection [28]. The government's policies on the real estate market are also not strict enough. In addition, residents of economically underdeveloped areas are more sensitive to changes in housing demand [5], which makes the increase in energy consumption and carbon emissions resulting from the development of the real estate sector more significant. Finally, the economically developed regions have an optimal allocation of social resources, resulting in much more efficient use of energy and more widespread use of green and clean energy, which effectively mitigates the effect of the development of the real estate sector to carbon emissions.

Based on the analysis above, Hypothesis 2 was proposed:

Hypothesis 2 (H2). *The impact of real estate development on carbon emissions varies by level of economic development and is greater in areas with a lower level of economic development.*

This study also considers the threshold effect of population size on the relationship between real estate development and carbon emissions. It affects the relationship between real estate development and carbon emissions by influencing housing demand: areas with larger populations have greater housing demand and larger real estate buying and selling markets, which lends a greater weight to the impact of real estate development on local carbon emissions and contributes to a more significant effect. In contrast, in areas with smaller population sizes, housing demand is limited, the development space and potential of real estate are restricted, and the degree of impact on carbon emissions decreases relative to areas with larger population sizes.

Based on the analysis above, Hypothesis 3 was proposed:

Hypothesis 3 (H3). *The impact of real estate development on carbon emissions varies by population size and is greater in areas with larger populations.*

3. Research Methodology

To verify the above hypothesis, the research methods of this paper are as follows: (1) The differential generalized method of moment estimation (DIF-GMM) is applied to effectively overcome the endogeneity problem prevalent in panel data, to systematically examine from a theoretical perspective the impact of real estate development on carbon emissions in China, and a quadratic term is added to examine possible non-linear effects. (2) Lagged one-period carbon emissions are added as an explanatory variable and dynamic panel threshold regression models are established to examine the threshold effect of economic development level and the threshold effect of population size between real estate development and carbon emissions in a dynamic perspective.

3.1. Variable Selection and Descriptive Statistics

Explained variable: Carbon emissions (CO_2). Based on previous research, there are two main types of international measures of carbon dioxide emissions: one is the direct calculation method, and the other is the exponential decomposition method [31,32]. The carbon emission data in this study are calculated by referring to Shan et al. and Guan et al. based on the measurement method provided by the IPCC sector, using various types of major energy consumption data and the corresponding carbon conversion factors [32–35].

Core explanatory variable: Real estate development. This study refers to Gong and Kong (2022) to use the amount of investment in real estate (*INVEST*) as a measure of real estate development [36]. To test the robustness of the findings, the average sales price of commercial housing units (*PRICE*) is also used in this study as a measure of real estate development [37]. On this basis, a quadratic term for the real estate development variable is added to examine the non-linear effect of real estate development on carbon emissions and to test whether there is a U-shaped or inverted U-shaped relationship between real estate development and carbon emissions.

Control variables: This study uses a series of control variables that may affect carbon emissions: (1) The level of regional economic development (GDP), which is measured by the gross regional product. Economic development will increase the energy demand thus promoting energy consumption and consequently enhancing carbon emissions. However, as the economy continues to develop, technology improves, and people become more aware of environmental protection, this will conversely suppress carbon emissions. (2) Population size (POPU), which is measured by the number of people living in the region at the end of the year. Human activities are the key contributors to energy consumption, and areas with larger populations consume more energy, thus contributing to more carbon emissions. (3) Urbanization rate (URBAN), which is measured by the proportion of the urban population to the total population of the region. As mentioned earlier, the effect of the urbanization rate on carbon emissions depends on the level of urbanization of the region, which appears to be a curve of first inhibition and then promotion. (4) Industry structure (ISU), which is measured by the ratio of the gross product of secondary and tertiary industries to GDP in each region. The impact of industry-structure upgrading on carbon emissions appears to have geographical differences, demonstrating a suppressive effect in some countries and regions and a promotional effect in other countries and regions [38,39]. The statistical software used in this paper is Stata16.0; descriptive statistics for all explanatory variables, core explanatory variables, and control variables are shown in Table 1.

Table 1. Descriptive statistics of variables.

Variable	Sample Capacity	Mean	Standard Deviation	Min	Max	Unit
CO_2	510	302.49	260.11	7.55	1700.04	Million Tons
PRICE	510	5366.85	4756.20	964.00	38,433.00	RMB/m^2
INVEST	510	257.08	294.85	2.28	2211.24	RMB billion
GDP	510	16,680.20	17,041.81	385.00	107,987.00	RMB billion
POPU	510	4470.57	2730.87	534.00	12,489.00	Ten Thousand People
URBAN	510	53.11	14.55	24.77	89.60	%
ISU	510	88.67	6.10	65.80	99.70	%

3.2. Data Sources

Limited by the completeness and availability of the original data, this study uses a balanced panel data from 2003 to 2019 for 30 provinces and municipalities directly under the Central Government and autonomous regions of China with a total of 510 observations. The original data in this study are mainly obtained from the China Statistical Yearbook, the annual statistical yearbooks of each region, and the China Energy Statistical Yearbook for each year. A linear interpolation method was used to supplement the small amount of the missing data.

3.3. Econometric Model Construction

The direct impact of real estate development on carbon emissions will be considered first in this study. Given the path-dependent inertia characteristic of carbon dioxide emissions [40], this paper added a one-period lag of carbon emissions as an explanatory variable into the model and constructs a dynamic panel model to examine the impact of past carbon emissions on current carbon emissions in the same region. The quadratic term of the real estate development measurement indicators (*INVEST*; *PRICE*) are also added to investigate the possible non-linear relationship between real estate development and carbon emissions. To mitigate the effect of heteroskedasticity on the study results, all variables were logarithmically transformed. The specific models were built as follows:

$$ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ INVEST_{it} + \alpha_2 ln\ {INVEST^2}_{it} + \alpha_3 ln\ CO2_{it-1} + \beta lnX_{it} + \varepsilon_{it} \quad (1)$$

$$ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ PRICE_{it} + \alpha_2 ln\ {PRICE^2}_{it} + \alpha_3 ln\ CO2_{it-1} + \beta lnX_{it} + \varepsilon_{it} \quad (2)$$

In Model (1), "*i*" denotes provinces and municipalities directly under the Central Government and autonomous regions of China (*i* = 1, 2, 3 ... 30); "*t*" denotes the year; "*ln*" denotes the natural logarithm form; "CO_2" denotes carbon emissions; "*INVEST*" is the amount of investment in real estate, which is used as a measure of the real estate development, while "*INVEST2*" is the quadratic term of it. "*X*" denotes the control variables, including the level of regional economic development, population size, urbanization rate, and industry structure; "ε" denotes the random disturbance terms. Model (2) is a robustness test for model (1), "*PRICE*" denotes house price, replacing "*INVEST*" in the model (1) to measure real estate development, and the meaning of the rest indicators remains unchanged. The inclusion of explanatory variables with a one-period lag in models (1) and (2) leads to the fact that traditional OLS or fixed-effect model estimation methods will be biased due to endogeneity issues. Arellano and Bond proposed the differential generalized method of moment estimation (DIF-GMM) in 1991 to effectively address the endogeneity of panel data to obtain more robust estimation results [16]. Considering the issue of the validity of instrumental variables, this study uses up to three lags of the explanatory variables as instrumental variables and applies the DIF-GMM method instead of the traditional panel model estimation method to explore the potential relationship between China's real estate development and carbon emissions.

Next, based on the preliminary verification of the impact of real estate development on carbon emissions, dynamic panel data threshold regression models are developed to examine the possible threshold effects between real estate development and carbon emissions. In this study, the level of economic development (*ln GDP*) and the size of the population (*ln POPU*) were chosen as the two threshold variables. Firstly, the significance of the threshold effects of the threshold variables was tested, then the specific number of thresholds and threshold values corresponding to the two threshold variables were further estimated, to investigate whether there is a distinction in the degree of impact of real estate development on carbon emissions at different intervals of economic development level and population size. The dynamic panel threshold regression models have been widely used in various research areas, such as economics [41], environmental sciences [42], and political science [43]. Hansen first developed a static panel threshold model based on fixed effects in 1999, but its drawback was the requirement to satisfy the strong exogeneity of the explanatory variables [44]. To broaden the model application assumptions and to extend the panel threshold model to a dynamic situation, Kremer et al. further proposed a dynamic panel data threshold model in 2013 [45]. With reference to Kremer et al., this study first established two single-threshold dynamic panel models using *ln GDP* and *ln POPU* as the threshold variables, respectively:

$$ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ INVEST_{it} \times I(ln\ GDP_{it} \leq \lambda) + \alpha_2 ln\ INVEST_{it} \times I(ln\ GDP_{it} > \lambda) + \alpha_3 ln\ CO2_{it-1} + \beta lnX_{it} + \varepsilon_{it} \quad (3)$$

$$ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ INVEST_{it} \times I(ln\ POPU_{it} \leq \lambda) + \alpha_2 ln\ INVEST_{it} \times I(ln\ POPU_{it} > \lambda) + \alpha_3 ln\ CO2_{it-1} + \beta lnX_{it} + \varepsilon_{it} \quad (4)$$

In Model (3), "λ" is the threshold value to be estimated and "$I(\cdot)$" represents the threshold indicative function; if the expression in brackets is true, then $I(\cdot) = 1$, otherwise $I(\cdot) = 0$. It can be seen that the estimated coefficients of the impact of real estate development on carbon emissions are α_1 for the case where the level of economic development is below the threshold value ($lnGDP_{it} \leq \lambda$) or α_2 for the case where the level of economic development is above the threshold value ($lnGDP_{it} > \lambda$). The threshold-effect significance test for Model (3) is a test of the hypothesis *H0*: $\alpha_1 = \alpha_2$. If the original hypothesis is rejected, it proves that there are significant differences in the extent to which real estate development affects carbon emissions in regions with different levels of economic development. The threshold variable in Model (4) is replaced with $ln\ POPU_{it}$ to investigate the differences in the impact of real estate development on carbon emissions under the different intervals of population size. The rest of the symbols in Models (3) and (4) are identical in meaning to Model (1).

Models (3) and (4) only set a single threshold, but in fact it is possible to have two thresholds, λ_1 and λ_2, for the threshold variables, so the double-threshold dynamic panel Model (5) and Model (6), with the level of economic development and population size as the threshold variables, respectively, were established. The estimated coefficients of the impact of real estate development on carbon emissions, respectively, are α_1, α_2 and α_3 for the three economic development level intervals of $lnGDP_{it} \leq \lambda_1$, $\lambda_1 < lnGDP_{it} \leq \lambda_2$ and $lnGDP_{it} > \lambda_2$ in Model (5). Model (6) is obtained by replacing the threshold value with population size along the same rules; the three population size intervals, respectively, were $ln\ POPU_{it} \leq \lambda_1$, $\lambda_1 < ln\ POPU_{it} \leq \lambda_2$, and $ln\ POPU_{it} > \lambda_2$. Model (5) and Model (6) are formulated as follows:

$$\begin{gathered} ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ INVEST_{it} \times I(lnGDP_{it} \leq \lambda_1) + \alpha_2 ln\ INVEST_{it} \times I(\lambda_1 < lnGDP_{it} \leq \lambda_2) + \alpha_3 ln\ INVEST_{it} \times I(lnGDP_{it} > \lambda_2) \\ + \alpha_4 ln\ CO2_{it-1} + \beta lnX_{it} + \varepsilon_{it} \end{gathered} \quad (5)$$

$$ln\ CO2_{it} = \alpha_0 + \alpha_1 ln\ INVEST_{it} \times I(ln\ POPU_{it} \leq \lambda_1) + \alpha_2 ln\ INVEST_{it} \times I(\lambda_1 < ln\ POPU_{it} \leq \lambda_2) + \alpha_3 ln\ INVEST_{it} \times I(ln\ POPU_{it} > \lambda_2) + \alpha_4 ln\ CO2_{it-1} + \beta ln X_{it} + \varepsilon_{it} \quad (6)$$

4. Results and Discussion

4.1. Tests for Data Stationarity and Cointegration

To exclude the possible spurious regression, stationarity tests were first conducted on the panel data. Table 2 demonstrates the results of the three panel unit root tests (LLC, Fisher-ADF and Fisher-PP) used in this study. The obtained results of the tests are shown in Table 2; it is evident from this that there are no panel unit roots for each of the variables at the 1% significance level, which means all the variables are significantly stationary.

Table 2. Panel unit root test results.

Variables	LLC	Fisher-ADF (Pm)	Fisher-PP (Pm)
ln CO2	−4.004 ***	7.650 ***	2.502 ***
ln PRICE	−4.812 ***	10.977 ***	6.155 ***
ln INVEST	−6.214 ***	3.832 ***	3.565 ***
ln GDP	−4.558 ***	4.682 ***	2.831 ***
ln POPU	−12.417 ***	7.131 ***	17.596 ***
ln URBAN	−19.507 ***	6.444 ***	15.756 ***
ln ISU	−5.120 ***	10.148 ***	5.779 ***

Note. *** denotes significance at 1%.

Cointegration tests were also performed on the panel data to test whether there is a stable equilibrium relationship between the series. In this study, Pedroni and Westerlund panel cointegration tests are conducted for the panel data [46,47]. As shown in Table 3, the cointegration relationships exist between the variables at the 1% significance level.

Table 3. Panel cointegration test results.

Test Methods		Statistics	*p* Value
Pedroni test	Modified Phillips–Perron t	7.664 ***	0.000
	Phillips–Perron t	−22.302 ***	0.000
Westerlund test	Augmented Dickey–Fuller t	−29.528 ***	0.000
	Variance ratio	30.758 ***	0.000

Note. *** denotes significance at 1%.

4.2. Differential GMM Estimation Results

The impact of real estate development on carbon emissions was then tested using a differential GMM approach. As can be seen in Table 4, in models (1) and (2), the *p*-value of the first-order series AR (1) test for the residual term is significant at the 5% level, while the *p*-value of the second-order series AR (2) test is not significant, indicating that there is no autocorrelation problem in the series, and the selection of the differential GMM estimation method is valid. Both models (1) and (2) passed the Sargen test, confirming the selection of instrumental variables without overidentification problems. The explanatory variable in model (1) is the amount of investment in real estate (*INVEST*) and the explanatory variable is carbon emissions. The coefficient of the explanatory variable *ln INVEST* is 0.395, which is significantly positive at the 1% level. This indicates that the rapid development of real estate in China has inevitably caused a large amount of energy consumption and carbon emissions. The coefficient of its quadratic term *ln INVEST2* is −0.035, which is significantly negative at the 1% level, confirming that there is a non-linear relationship between China's real estate development and carbon emissions. The result shows that when the *ln INVEST* is lower than 11.286, real estate development will have a significant positive contribution to carbon emissions. Only when the *ln INVEST* more than 11.286 will the inhibitory effect of real estate development on carbon emissions be apparent. However, considering the status and pace of real estate development in China, it will take a very long time to reach the latter stage. Therefore, H1 proposed in this paper is proven: the real estate development will play a significant role in promoting China's carbon emissions for a long period in the future.

Table 4. Differential GMM estimation results.

Variables	*ln CO2*	
	Model (1)	**Model (2)**
lnINVEST	0.395 *** (0.123)	/
$lnINVEST^2$	−0.035 *** (0.012)	/
lnPRICE	/	2.398 *** (0.579)
$lnPRICE^2$	/	−0.137 *** (0.034)
ln CO2 with a one-period lag	0.588 *** (0.041)	0.525 *** (0.024)
lnGDP	0.119 ** (0.052)	0.135 *** (0.051)
lnURBAN	−0.434 *** (0.149)	−0.450 *** (0.151)
lnPOPU	0.030 *** (0.012)	0.012 (0.014)
lnISU	1.132 (0.715)	0.324 (0.497)
Constant Term	−3.508 (2.746)	−8.899 *** (2.294)
AR (1)	−2.093 ** [0.036]	−2.109 ** [0.035]
AR (2)	0.598 [0.550]	0.907 [0.365]
Sargon	24.120 [1.000]	25.620 [1.000]

Note. Data in small brackets are standard errors, data in middle brackets are *p*-values. *** and ** denote significance at 1% and 5%.

In addition, the coefficient of the one-period lag carbon emissions is 0.588 and passes the significance test at the 1% level, indicating that in model (1) of this study, the current period's carbon emissions are most influenced by the previous period's carbon emissions. The coefficient of population size on carbon emissions is 0.03 and is significant at the 1% level; this may because the high level of human capital in a region with a large population, as well as rapid technological innovation, which increases the level of regional energy-saving and emission-reduction technology and the energy-utilization efficiency. The coefficient of 0.119 for the economic development level is significant at the 5% level. This may because China's rapid economic growth has been accompanied by a great deal of industrialization, and the large amount of fossil energy consumed in the process is increasing China's total carbon emissions. The coefficient of the urbanization rate is −0.434 and have a significant negative effect at the 1% level. This may because the accelerated urbanization process has accelerated technological innovation in the region, which improves the utilization of regional infrastructure and energy-use efficiency, ultimately easing the pressure to reduce carbon emissions from a technological perspective.

Model (2) is a robust test of Model (1), in which the core explanatory variable and its quadratic term of real estate development are replaced by *ln INVEST* with *ln PRICE*, while all other variables remain unchanged. Table 4 shows that after replacing the core explanatory variables, the regression results of Model (2) are generally consistent with those of Model (1). The coefficient on the primary term of the relationship between real estate development and carbon emissions remains significantly positive at the 1% level and the coefficient on the quadratic term remains significantly negative at the 1% level, indicating that the model chosen in this study is robust and valid.

4.3. Analysis of Threshold Effects Using the ln GDP as a Threshold

To test the threshold effect of the level of economic development, Models (3) and (5) with the level of economic development (ln GDP) as the threshold variable were first estimated. The number of thresholds for the variables, the threshold value, their 95% confidence intervals, and the significance tests for the threshold effects are shown in Table 5. In the single-threshold Model (3), the threshold effect for the level of economic development is significant at the 5% level, which demonstrates the existence of a non-linear threshold effect on the impact of real estate development on carbon emissions. However, the threshold effect is not significant in the double-threshold Model (5), indicating that Model (3) should be used for the rest of the analysis. The threshold value for *ln GDP* is 9.904, which corresponds to a regional GDP of RMB 20,010.252 billion, confirming that there is a significant difference in the impact of real estate development on carbon emissions between the low economic development level interval ($ln\ GDP \leq 9.904$) and the high economic development level interval ($ln\ GDP > 9.904$).

Table 5. Estimation of the threshold value and test of threshold effect of economic development level.

Threshold Variable	Number of Thresholds	Threshold Value	F Value	*p* Value	95% Confidence Intervals	1%	5%	10%
ln GDP	Single-Threshold **	9.904	19.620	0.013	[9.875, 9.905]	19.774	15.224	13.213
	Double-Threshold	8.720	7.380	0.340	[8.702, 8.739]	18.780	14.700	12.390

Note. The value of bootstrap in the above test is 300. ** denotes significance at 5%.

The results in Table 6 show the non-linear effects of real estate development on carbon emissions as estimated from a dynamic panel single threshold model with the level of economic development as the threshold. A positive correlation between real estate development and carbon emissions is observed at both low and high levels of economic development: with the threshold effect, the coefficient is 0.036 and significant at the 1% level for lower economic development; the interval is 0.026 and significant at the 5% level for higher economic development, which demonstrates that the effect of real estate development on carbon emissions varies by economic development level. This demonstrates the role of real estate development in its building and maintenance phases and in incentivizing the development of its related industries such as steel and cement manufacturing; both consume a lot of energy and ultimately contribute to carbon emissions. It is also observed that the estimated coefficient between the impact of real estate development on carbon emissions is greater in the low economic development interval than in the high economic development interval. When the ln GDP is less than the threshold value of 9.904, i.e., when the regional GDP is less than RMB 20,010.252 billion, every 1% increase in the level of real estate development will boost carbon emissions by 0.036%; while when the threshold value is crossed, the ln GDP is more than the threshold value of 9.904, i.e., when the regional GDP is greater than RMB 20,010.252 billion, every 1% increase in the level of real estate development will only boost carbon emissions by 0.026%. The marginal contribution of real estate development to carbon emissions in economically developed regions is reduced. H2 is thus confirmed: economically developed regions tend to attract more highly educated and qualified people than less developed regions, and these people will be more self-aware about environmental protection and energy saving [48]. In addition, the economically developed regions have a more reasonable allocation of resources, more efficient utilization of energy, and more extensive use of clean energy. All of these lead to the development of the real estate sector in economically developed regions having a relatively lower impact on energy consumption and carbon emissions.

4.4. Analysis of Threshold Effects Using the ln POPU as a Threshold

To explore the relationship between real estate development and carbon emissions under different population size intervals, this study estimates Models (4) and (6) with population size (*ln POPU*) as the threshold variable. The number of thresholds for the variables, the threshold value, their 95% confidence intervals, and the significance tests for the threshold effects are shown in Table 7. The threshold effect of population size in the single-threshold model (4) is significant at the 5% level, while the threshold effect in the double-threshold model (6) is not significant, demonstrating that Model (4) should be used for the rest analysis. The threshold variable ln POPU has a threshold value of 7.839, corresponding to a population size of 25,376.66 thousand people. The result illustrates that there is a significant difference in the impact of real estate development on carbon emissions in the low population size interval (*ln POPU* ≤ 7.839) and the high population size interval (*ln POPU* > 7.839).

Table 6. Non-linear effects of real estate development on carbon emissions (with *ln GDP* as a threshold).

Variables	*ln CO2*		
	Coefficient	**Standard Error**	***p* Value**
ln INVEST (*ln GDP* ≤ 9.904)	0.036 ***	0.011	0.001
ln INVEST (*ln GDP* > 9.904)	0.026 **	0.011	0.021
Constant Term	−0.672	1.114	0.547
Other Control Variables		controlled	
F value		5.430 ***	

Note. *** and ** denote significance at 1% and 5%.

Table 7. Estimation of the threshold value and test of threshold effect of population size.

Threshold Variable	Number of Thresholds	Threshold Value	F Value	*p* Value	95% Confidence Intervals	1%	5%	10%
ln POPU	Single-threshold **	7.839	8.420	0.033	[7.836, 7.842]	9.860	7.860	6.178
	Double Threshold	8.211	0.840	0.940	[8.188, 8.213]	9.441	6.414	5.454

Note. The value of bootstrap in the above test is 300. ** denote significance at 5%.

Table 8 shows the non-linear effects of real estate development on carbon emissions estimated from a dynamic panel single-threshold model with population size as the threshold. The threshold effect is significant at the 1% level for the lower population size interval and at 5% level for the higher population size interval. This suggests that the impact of real estate development on carbon emissions is moderated by a significant threshold effect of population size, but both are positive. In the low population interval, a 1% increase in the level of real estate development will increase carbon emissions by 0.031%, and when the population size crosses the threshold value to reach the high population size interval, the positive impact of the level of real estate development on the increase in carbon emissions is enhanced, with each 1% increase in the level of real estate development increasing carbon emissions by 0.036%. This confirms our previous H3: regions with larger populations have larger real estate consumption markets and residents have a stronger demand for buying a house, so real estate development has a more pronounced positive impact on the increase in carbon emissions. In areas with smaller population sizes, where demand for housing is limited, changes in the real estate market will cause a smaller shift in carbon emissions than in the manufacturing and other carbon emission sectors. These have led to a relatively small degree of impact of real estate development on local carbon emissions in those regions.

Table 8. Non-linear effects of real estate development on carbon emissions (with *ln POPU* as a threshold).

Variables	*ln CO2*		
	Coefficient	**Standard Error**	***p* Value**
ln INVEST (*ln POPU* ≤ 7.839)	0.031 **	0.013	0.014
ln INVEST (*ln POPU* >7.839)	0.036 ***	0.013	0.005
Constant Term	0.408	1.117	0.715
Other Control Variables		controlled	
F value		5.080 ***	

Note. *** and ** denote significance at 1% and 5%.

Overall, real estate development has a positive contribution to carbon emissions in China. However, this non-linear contribution is influenced by the level of regional economic development and the size of the regional population. When the level of regional economic development is lower, the contribution of real estate development to carbon emissions is more significant. In addition, in areas with larger populations, the contribution of real estate development to the increase in local carbon emissions is more pronounced.

5. Conclusions and Policy Implications

5.1. Conclusions

To examine the potential relationship between China's real estate development and carbon emissions, this study has applied a differential GMM method and built dynamic panel data threshold regression models to empirically analyze the balanced panel data from 30 provinces and municipalities directly under the Central Government and autonomous regions of China (excluding the Hong Kong, Macao, and Taiwan regions and Tibet Province). The impact of real estate development on carbon emissions and the threshold effect of the impact at different levels of economic development and population sizes were examined, and the following conclusions were drawn: (1) Consistent with previous studies, the primary term of the coefficient of the impact of real estate development on carbon emissions is positive [4,5]. However, this study also found that there is a non-linear relationship between real estate development and carbon emissions; the coefficient of the quadratic term is significantly negative, indicating that as the level of real estate development increases, its impact on carbon emissions tends to first rise and then decline, but given the current condition of development of China's real estate industry, it will be in a state of promotion for a very long time. (2) The promotion effect of real estate development on carbon emissions varies with the level of regional economic development. More specifically, the influence of real estate development on carbon emissions decreases when the regional GDP is greater than RMB 20,010.252 billion. (3) Population size also plays a threshold role in the promotion of real estate development on carbon emissions, with real estate development having a more pronounced promotion effect on carbon emissions when the total regional population exceeds the threshold value of 25,376.66 thousand people.

5.2. Policy Implications

Based on the above findings, this study makes some recommendations. Firstly, the negative impact of the rapid growth of real estate and related industries on China's goal of achieving "carbon peaking" and "carbon neutrality" must be taken seriously. It is urgent that China's real estate industry makes transformations to be lower carbon and environmentally friendly. To achieve this, China's relevant state departments should work together with the related institutions and professionals, to promote the formulation, improvement, and implementation of laws and standards concerning the whole real estate industry chain of green and low-carbon real estate construction and maintenance. It is also necessary to strengthen the political intention and intrinsic motivation of local governments to build a green and low-carbon real estate industry. Specific plans appropriate to the local context should be established and implemented, and responsibility of all stakeholders in the entire real estate chain for green and low car-bon development goals should also be made clear. At the same time, a production and consumption dual-way incentive policy and mechanism for energy-saving and emission-reduction in the real estate sector should be established, to gradually form a "government-led, corporate-dominated and public participation" long-term mechanism for low-carbon sustainability in the real estate industry. Specific approaches in terms of technology include selecting low-carbon building materials and semi-finished or finished products to reduce hidden carbon in buildings, adopting assembly construction methods, improving building energy efficiency to reduce energy consumption in building operation, building electrification and enhanced building carbon footprint disclosure, etc.

Secondly, a green and low-carbon synergistic development strategy should be implemented nationwide according to the differences in regional levels of economic development and differentiated real estate regulation, and control policies should be formulated to promote the synergistic development of green and low-carbon real estate markets in various regions. Along with the accelerated urbanization process in China, it is necessary to change the development mode to better optimize the spatial layout of urban and rural areas and improve the quality of urban functions. In the future, real estate and urban-rural development should first be based on the urban-rural spatial pattern with urban clusters as the main form, then develop and grow urban clusters and urban circles to carry out and optimize the functions of China's urban centers and drive the surrounding cities to form clusters. In the meanwhile, emphasis should be placed on building on strengths and avoiding weaknesses in the construction process. For example, the comprehensive governance capacity of small cities should be improved, and the advantages of small towns should be brought into play in accordance with local conditions to provide a basic platform for new-type urbanization. The construction of linkages between the county and the countryside should also be planned in an integrated and comprehensive way to drive up the level of public infrastructure construction in rural areas and build a modern and habitable countryside.

Lastly, China's urbanization has entered a new phase; the era of large-scale demolition and construction of real estate development has become history. In the future, real estate development should pay more attention to environmental protection and social capital inputs. Regions with large populations should take the first step and real estate development should be closely integrated with urban and rural synergistic development strategies; the focus should be on the protection of habitats and the environment and the promotion of urban and rural ecology. New ideas for further development are needed, with efforts to build a green and low-carbon development pattern under the guideline of "government-led and social participation". It is reasonable to believe that driven by the above-mentioned innovative theories and practices, China will be able to build a long-term mechanism for the sustainable and healthy development of real estate in accordance with local conditions, which will contribute to the achievement of "carbon peaking" and "carbon neutrality" goals.

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References

1. National Bureau of Statistics of China. 2004. Available online: http://www.stats.gov.cn/sj/ndsj/yb2004-c/indexch.htm (accessed on 23 October 2022).
2. National Bureau of Statistics of China. 2020. Available online: http://www.stats.gov.cn/sj/ndsj/2020/indexch.htm (accessed on 23 October 2022).
3. Zhu, Y.; Huo, C.J. The Impact of Agricultural Production Efficiency on Agricultural Carbon Emissions in China. *Energies* **2022**, *15*, 4464. [CrossRef]
4. Fan, J.S.; Zhou, L. Impact of urbanization and real estate investment on carbon emissions: Evidence from China's provincial regions. *J. Clean. Prod.* **2019**, *209*, 309–323. [CrossRef]
5. Yu, S.W.; Hu, X.; Yang, J. Housing prices and carbon emissions: A dynamic panel threshold model of 60 Chinese cities. *Appl. Econ. Lett.* **2020**, *28*, 170–185. [CrossRef]

6. Guo, J.; Zhang, Y.J.; Zhang, K.B. The key sectors for energy conservation and carbon emissions reduction in China: Evidence from the input-output method. *J. Clean. Prod.* **2018**, *179*, 180–190. [CrossRef]
7. Martinsen, D.; Krey, V.; Markewitz, P. Implications of high energy prices for energy system and emissions-The response from an energy model for Germany. *Energy Policy* **2007**, *35*, 4504–4515. [CrossRef]
8. Xu, S.C.; He, Z.X.; Long, R.Y. Factors that influence carbon emissions due to energy consumption in China: Decomposition analysis using LMDI. *Appl. Energy* **2014**, *127*, 182–193. [CrossRef]
9. Cheng, S.P.; Meng, L.J.; Xing, L. Energy technological innovation and carbon emissions mitigation: Evidence from China. *Kybernetes* **2022**, *51*, 982–1008. [CrossRef]
10. Fang, D.L.; Duan, C.C.; Chen, B. Average propagation length analysis for carbon emissions in China. *Appl. Energy* **2020**, *275*, 115386. [CrossRef]
11. Xu, G.Y.; Zhao, T.; Wang, R. Research on Carbon Emission Efficiency Measurement and Regional Difference Evaluation of China's Regional Transportation Industry. *Energies* **2022**, *15*, 6502. [CrossRef]
12. Tang, Y.L.; Zhu, H.M.; Yang, J. The asymmetric effects of economic growth, urbanization and deindustrialization on carbon emissions: Evidence from China. *Energy Rep.* **2022**, *8*, 513–521. [CrossRef]
13. Zheng, Y.M.; Lv, Q.; Wang, Y.D. Economic development, technological progress, and provincial carbon emissions intensity: Empirical research based on the threshold panel model. *Appl. Econ.* **2021**, *54*, 3495–3504. [CrossRef]
14. Wang, Q.; Dong, Z.Q. Does financial development promote renewable energy? Evidence of G20 economies. *Environ. Sci. Pollut. Res.* **2021**, *28*, 64461–64474. [CrossRef]
15. Wang, Z.H.; Yang, J.; Jiang, J.Q. Urban Sprawl and Haze Pollution: Based on Raster Data of Haze PM2.5 Concentrations in 283 Cities in Mainland China. *Front. Environ. Sci.* **2022**, *10*, 929558. [CrossRef]
16. Arellano, M.; Bond, S. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Rev. Econ. Stud.* **1991**, *58*, 277–297. [CrossRef]
17. Lu, W.C. The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. *Mitig. Adapt. Strateg. Glob. Chang.* **2018**, *23*, 1351–1365. [CrossRef]
18. Bianco, V.; Cascetta, F.; Marino, A.; Nardini, S. Understanding energy consumption and carbon emissions in Europe: A focus on inequality issues. *Energy* **2019**, *270*, 120–130. [CrossRef]
19. Chen, X.; Chen, Y.E.; Chang, C.P. The effects of environmental regulation and industrial structure on carbon dioxide emission: A non-linear investigation. *Environ. Sci. Pollut. Res.* **2019**, *26*, 30252–30267. [CrossRef]
20. Dong, F.; Wang, Y.; Su, B.; Hua, Y.F.; Zhang, Y.Q. The process of peak CO_2 emissions in developed economies: A perspective of industrialization and urbanization. *Resour. Conserv. Recycl.* **2019**, *141*, 61–75. [CrossRef]
21. Al-mulali, U.; Binti Che Sab, C.N.; Fereidouni, H.G. Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. *Energy* **2012**, *46*, 156–167. [CrossRef]
22. Tan, X.L.; Zhou, H.; Jiang, S.C.; Liang, S. Study on the impact of population factors on real estate price of Jilin city based on regression model. In Proceedings of the World Automation Congress 2012, Taiwan, China, 24 June 2012.
23. Kong, Y.; Glascock, J.L.; Lu-Andrews, R. An Investigation into Real Estate Investment and Economic Growth in China: A Dynamic Panel Data Approach. *Sustainability* **2016**, *8*, 66. [CrossRef]
24. Liu, T.Y.; Su, C.W.; Chang, H.L.; Chu, C.C. Is urbanization improving real estate investment? A cross-regional study of China. *Rev. Dev. Econ.* **2018**, *22*, 862–878. [CrossRef]
25. Vimpari, J. Should energy efficiency subsidies be tied into housing prices? *Environ. Res. Lett.* **2021**, *16*, 064027. [CrossRef]
26. Sun, Z.Z. An Empirical Study on the Relationship between Education and Economic Development Based on PVAR Model. *Sci. Program.* **2021**, *2021*, 6052182. [CrossRef]
27. Kan, D.X.; Lyu, L.J.; Huang, W.C.; Yao, W.Q. The Impact of Urban Education on the Income Gap of Urban Residents: Evidence from Central China. *Sustainability* **2022**, *14*, 4493. [CrossRef]
28. Sun, L.X.; Yang, S.; Li, S.M.; Zhang, Y.D. Does education level affect individuals' environmentally conscious behavior? Evidence from Mainland China. *Soc. Behav. Personal.* **2020**, *48*, 1–12. [CrossRef]
29. Gao, Y.; Yang, G.; Xie, Q. Spatial-Temporal Evolution and Driving Factors of Green Building Development in China. *Sustainability* **2020**, *12*, 2773. [CrossRef]
30. Yan, H.; Fan, Z.Y.; Zhang, Y.B.; Zhang, L.; Hao, Z.B. A city-level analysis of the spatial distribution differences of green buildings and the economic forces—A case study in China. *J. Clean. Prod.* **2022**, *371*, 133433. [CrossRef]
31. He, W.; Wang, B.; Danish; Wang, Z. Will regional economic integration influence carbon dioxide marginal abatement costs? Evidence from Chinese panel data. *Energy Econ.* **2018**, *74*, 263–274. [CrossRef]
32. Shan, Y.L.; Liu, J.H.; Liu, Z.; Xu, X.W.H.; Shao, S.; Wang, P.; Guan, D.B. New provincial CO_2 emission inventories in China based on apparent energy consumption data and updated emission factors. *Appl. Energy* **2016**, *184*, 742–750. [CrossRef]
33. Shan, Y.L.; Guan, D.B.; Zheng, H.R.; Ou, J.M.; Li, Y.; Meng, J.; Mi, Z.F.; Liu, Z.; Zhang, Q. China CO_2 emission accounts 1997–2015. *Sci. Data* **2018**, *5*, 170201. [CrossRef]
34. Shan, Y.L.; Huang, Q.; Guan, D.B.; Hubacek, K. China CO_2 emission accounts 2016–2017. *Sci. Data* **2020**, *7*, 54. [CrossRef]
35. Guan, Y.R.; Shan, Y.L.; Huang, Q.; Chen, H.L.; Wang, D.; Hubacek, K. Assessment to China's recent emission pattern shifts. *Earth's Future* **2021**, *9*, e2021EF002241. [CrossRef]

36. Gong, W.Q.; Kong, Y. Nonlinear Influence of Chinese Real Estate Development on Environmental Pollution: New Evidence from Spatial Econometric Model. *Int. J. Environ. Res. Public Health* **2022**, *19*, 588. [CrossRef]
37. Li, J.T.; Ji, J.Y.; Guo, H.W.; Chen, L. Research on the Influence of Real Estate Development on Private Investment: A Case Study of China. *Sustainability* **2018**, *10*, 2659. [CrossRef]
38. Gu, R.D.; Li, C.F.; Li, D.D.; Yang, Y.Y.; Gu, S. The Impact of Rationalization and Upgrading of Industrial Structure on Carbon Emissions in the Beijing-Tianjin-Hebei Urban Agglomeration. *Int. J. Environ. Res. Public Health* **2022**, *19*, 7997. [CrossRef]
39. Dong, B.Y.; Xu, Y.Z.; Fan, X.M. How to achieve a win-win situation between economic growth and carbon emission reduction: Empirical evidence from the perspective of industrial structure upgrading. *Environ. Sci. Pollut. Res.* **2020**, *27*, 43829–43844. [CrossRef]
40. Wang, S.J.; Liu, X.P.; Zhou, C.S.; Hu, J.C.; Ou, J.P. Examining the impacts of socioeconomic factors, urban form, and transportation networks on CO_2 emissions in China's megacities. *Appl. Energy* **2017**, *185*, 189–200. [CrossRef]
41. Aydin, C.; Esen, Ö. Does the level of energy intensity matter in the effect of energy consumption on the growth of transition economies? Evidence from dynamic panel threshold analysis. *Energy Econ.* **2018**, *69*, 185–195. [CrossRef]
42. Luan, B.J.; Huang, J.B.; Zou, H. Domestic R&D, technology acquisition, technology assimilation and China's industrial carbon intensity: Evidence from a dynamic panel threshold model. *Sci. Total Environ.* **2019**, *693*, 133436.
43. Maddah, M.; Ghaffari Nejad, A.H.; Sargolzaee, M. Natural resources, political competition, and economic growth: An empirical evidence from dynamic panel threshold kink analysis in Iranian provinces. *Resour. Policy* **2022**, *78*, 102928. [CrossRef]
44. Hansen, B.E. Threshold effects in non-dynamic panels: Estimation, testing, and inference. *J. Econom.* **1999**, *93*, 345–368. [CrossRef]
45. Kremer, S.; Bick, A.; Nautz, D. Inflation and growth: New evidence from a dynamic panel threshold analysis. *Empir. Econ.* **2013**, *44*, 861–878. [CrossRef]
46. Pedroni, P. Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests, with an Application to the Ppp Hypothesis. *Econom. Theory* **2004**, *20*, 597–625. [CrossRef]
47. Westerlund, J. New Simple Tests for Panel Cointegration. *Econom. Rev.* **2005**, *24*, 297–316. [CrossRef]
48. Li, K.; Lin, B.Q. Metafroniter energy efficiency with CO_2 emissions and its convergence analysis for China. *Energy Econ.* **2015**, *48*, 230–241. [CrossRef]