

Does Energy Consumption Drive Housing Sales in China?

—Based on an Optimal Dynamic General Equilibrium Model and Spatial Panel Data Analysis

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Abstract

This paper examines the housing sales in China from 2004 to 2015 utilizing an optimal dynamic general equilibrium theoretical framework combined with a macroeconomic model. The spatial panel econometric empirical results suggest that energy consumption has increased housing sales in China. However, since house is considered as a special commodity in China, and housing prices show positive impacts on housing sales.

Keywords

Energy Use, Housing Values, Optimal Dynamic General Equilibrium, Spatial Panel Econometrics, China

1. Introduction

There are many studies on energy consumption [1] or urban housing prices in China [2] [3] [4] [5] [6], but not many that examine the nexus between energy consumption and housing sales. So, the objective of the paper is to examine the relationship between them. In this paper, we focus on the impact of energy consumption on housing sales in the optimal dynamic general equilibrium, in China from 2004 to 2015, applying panel data OLS and panel data spatial auto regression these two econometric approaches.

Currently, more and more scholars start to discuss the nexus between energy and housing issue. According to the mandatory energy performance certificates of the 2009-2010 in the Swedish private housing transactions [7] find that energy

performance is associated with transaction price in situations when it is conditional on a reference benchmark. They also document property price premiums for energy performance within housing segments built before 1960 and those with a lower transaction price per square meter, meaning that the property market values energy performance, so housing segments need policy support to encourage energy improvements.

As we know, in many developed countries, wind turbines are constructed as part of a strategy to reduce dependence on fossil fuels. Using a difference-in-differences methodology with a unique Dutch house price dataset covering the period 1985-2011, Dröes and Koster [8] find a 1.4% price decrease for houses within 2 km of a turbine in the Netherlands. The effect is larger for taller turbines and in urban areas. Especially the first turbine built close to a house has a negative effect on its price. Meanwhile, an analysis of the private rental segment reveals that, in contrast to the general market, low-Energy Performance Certificate (EPC) rated dwellings were not traded at a significant discount. This suggests different implicit prices of potential energy savings for landlords and owner-occupiers [9].

Obviously, the nexus between energy consumption and housing sales has not been pay attention to, according to the literature above. Hence, the theoretical and empirical contributions of this paper are that we utilize the Keynesian Optimal General Equilibrium Model and Panel Spatial Econometric Approach to analyze the effect of energy consumption on housing sales in China.

The structure of this paper is as follows. This introduction section provides a brief overview of prior research analyzing the housing prices and energy consumption. In Section 2, we set up the optimal dynamic general equilibrium theoretical model with the energy variable and combining the macroeconomic model in the determination of the sales of housing on province level. In Section 3, we present the data utilized in the analysis and introduce the econometric methods employed. The impacts on metropolitan housing sales are examined in Section 4 and Section 5 presents conclusions and further discussion.

2. Optimal Dynamic General Equilibrium Model with Energy and Housing Sector

2.1. Social Welfare Dynamic Optimization

In our optimal dynamic general equilibrium model, we assume the total social welfare maximization problem is expressed as below:

$$\max_{h_{t+s}, c_{t+s}} V_t = \sum_{s=0}^{\infty} \beta^s U(h_{t+s}, c_{t+s}) \quad (1)$$

where V_t represents the total social welfare from period 0 to infinite, $\beta = 1/(1 + \theta)$ represents the discount rate, U represents the social welfare function, h_{t+s} represents the housing consumption at the period $(t + s)$, and c_{t+s} represents other consumption except housing consumption. Given the law of diminishing marginal utility, the social welfare function has the property of strict qua-

si-concave, which means $U_{cc}, U_{hh} \leq 0$ and $U_{cc}, U_{hh} \leq 0$.

Suppose the accumulation equation of housing can be expressed as follows:

$$\Delta h_{t+1} = S_t + \gamma h_t \quad (2)$$

where S_t denotes the capacity of the real estate at the t period, and γ denotes the value-added rate. Furthermore, considering the budget constraints of the society being expressed as:

$$\Delta a_{t+1} + c_t + p_t^h h_t = x_t + r_t a_t + w_t L_t \quad (3)$$

where Δa_{t+1} represents the financial assets purchased at the $(t+1)$ period, p_t^h represents the price of the house at the t period, x_t represents the dividend income, r_t and a_t respectively represent the interest rate of financial assets at the t period and the stock of financial asset at the t period. w_t represents the wage at the t period and L_t represents the number of labor at the t period.

According to the Equations (1), (2) and (3), we can set up the Hamiltonian function:

$$H = U(c_{t+s}, h_{t+s}) + \lambda(x_{t+s} + r_{t+s} a_{t+s} + w_{t+s} n_{t+s} - c_{t+s} - p_{t+s}^h h_{t+s+1} + p_{t+s}^h (1 + \gamma) h_{t+s}) \quad (4)$$

The first order conditions are as below:

$$U_{c,t+s} - \lambda_{t+s} = 0 \quad (5)$$

$$U_{h,t+s} + \lambda_{t+s} p_{t+s}^h (1 + \gamma) - \lambda_{t+s-1} p_{t+s-1}^h = 0 \quad (6)$$

Combining (5) and (6), we obtain:

$$\frac{U_{c,t+1}}{U_{c,t}} (1 + r_{t+1}) = 1 \quad (7)$$

And the approximate solution of optimal housing consumption utility is expressed:

$$U_{h,t+1} = U_{c,t+1} p_{t+1}^h \left(-\frac{\Delta p_{t+1}^h}{p_t^h} - 1 - \gamma \right) \quad (8)$$

Suppose the social welfare function takes the Cobb-Douglas form:

$$U(c_t, h_t) = c_t^\alpha h_t^{1-\alpha}, \quad 0 < \alpha < 1 \quad (9)$$

$$\frac{c_{t+1}}{p_{t+1}^h h_{t+1}} = \frac{\alpha}{1-\alpha} \left(-\gamma - \frac{p_{t+1}^h}{p_t^h} \right) \quad (10)$$

$$h_{t+1} = \frac{c_{t+1} (1-\alpha)}{p_{t+1}^h \alpha \left(-\gamma - \frac{p_{t+1}^h}{p_t^h} \right)} \quad (11)$$

2.2. Energy Firm Production

Suppose the total output in the society is the function of labor and energy input.

$$Y_t = F(EC_t, L_t) \quad (12)$$

where EC_t denotes the stock of energy used at period t , so the accumulated

energy use equation is: $\Delta EC_{t+1} = i_t - \delta EC_t$, i_t denotes the flow of energy consumed or investment on energy extraction at period t and δ denotes average extraction cost of energy.

In the profit maximization equilibrium point, the first order condition requires the wage is identical to the marginal output of labor, and the marginal output of energy is identical to the extraction cost of the energy:

$$F_{n,t+s} = w_t \quad (13)$$

$$F_{EC,t+s} = \delta \quad (14)$$

Given energy stocks and specific technical level, higher real wages will increase labor demand. Similarly, the demand for energy is $F_{k,t+1}^{-1}(\delta)$, and the flow of energy equation can be expressed:

$$i_t = F_{k,t+1}^{-1}(\delta) - (1 - \delta)EC_t \quad (15)$$

2.3. The Real Estate Sector

We assume the demand for real estate is a negatively sloped linear function as follows:

$$h_t = g + kp_t^h \quad (k < 0) \quad (16)$$

The Equation (16) can be expressed as follows:

$$kp_t^h = h_t - g \Rightarrow p_t^h = \frac{h_t - g}{k}$$

On the other hand, the supply function can be expressed as:

$$p_t^h = C_0 + C_1 S_t \quad (17)$$

where C_0 represents fixed cost due to the real estate construction and C_1 represents the marginal cost of real estate for construction. Combining (16) and (17), we have

$$h_t^* = g + kC_0 + C_1 k S_t \quad (18)$$

The difference equation which describes the housing capacity as a function of time is obtained by equating “come in market” minus “come out market” with the impact on the housing capacity, namely,

$$S_{t+1} = R_t + (s - 1)h_t \quad (19)$$

where R_t is new building entering the housing market, s is return flow into market coefficient. From (18) and (19), we have

$$\begin{aligned} S_{t+1} &= R_t + (s - 1)(g + kC_0 + C_1 k S_t) \\ &= R_t + (s - 1)C_1 k S_t + (s - 1)g + (s - 1)kC_0 \end{aligned} \quad (20)$$

$$\Rightarrow S_{t+1} + (1 - s)C_1 k S_t = R_t + (s - 1)g + (s - 1)kC_0 \quad (21)$$

The solution of (21) is as below:

$$\begin{aligned} S_t^* &= \left[S_0 - \frac{R_t + (s - 1)g + (s - 1)kC_0}{1 + (1 - s)C_1 k} \right] [(s - 1)C_1 k]^t \\ &\quad + \frac{R_t + (s - 1)g + (s - 1)kC_0}{1 + (1 - s)C_1 k} \end{aligned} \quad (22)$$

Combining (18) and (22), we have:

$$h_t^* = C_1 k \left[S_0 - \frac{R_t + (s-1)g + (s-1)kC_0}{1 + (1-s)C_1 k} \right] \left[(s-1)C_1 k \right]^t + C_1 k \frac{R_t + (s-1)g + (s-1)kC_0}{1 + (1-s)C_1 k} + g + kC_0 \quad (23)$$

Similarly, combining (17) and (22), we have:

$$p_t^{h*} = C_1 \left[S_0 - \frac{R_t + (s-1)g + (s-1)kC_0}{1 + (1-s)C_1 k} \right] \left[(s-1)C_1 k \right]^t + C_1 \left[S_0 - \frac{R_t + (s-1)g + (s-1)kC_0}{1 + (1-s)C_1 k} \right] + C_0 \quad (24)$$

It is assumed that the total output function is $Y_t = u_t EC_t^a L_t^b$, and u_t is the level of industrialization at t period, which is transferred into logarithmic form:

$$\ln Y_t = a \ln EC_t + b \ln L_t + \ln u_t \quad (25)$$

Let NX_t denote the net export, the total consumption is:

$$TC_t = c_t + h_t p_t^h + NX_t = \frac{\alpha}{\alpha-1} p_t^h \left(\gamma + \frac{p_t^h}{p_{t-1}^h} \right) p_t^h h_t + h_t p_t^h + NX_t \quad (26)$$

According to the national income equity with the government expenditure (G_t), we have

$$Y_t = TC_t + i_t + G_t = \left[\frac{\alpha}{\alpha-1} (p_t^h)^2 \left(\gamma + \frac{p_t^h}{p_{t-1}^h} \right) + p_t^h \right] h_t + NX_t + F_{k,t+1}^{-1} (\delta + r) - (1-\delta) EC_t + G_t \quad (27)$$

When the economy system reaches the steady state, the (27) is expressed as:

$$\ln Y_t = \ln \left[\frac{\alpha}{\alpha-1} (p_t^h)^2 \left(\gamma + \frac{p_t^h}{p_{t-1}^h} \right) + p_t^h \right] + \ln h_t + \ln [F_{k,t+1}^{-1} (\delta)] - \ln [(1-\delta) EC_t] + \ln G_t \quad (28)$$

The Equation (28) is further transformed into:

$$\ln h_t = (a+1) \ln (EC_t) + b \ln L_t + \ln u_t - \ln \left[\frac{\alpha}{\alpha-1} (p_t^h)^2 \left(\gamma + \frac{p_t^h}{p_{t-1}^h} \right) + 1 \right] - \ln [F_{k,t+1}^{-1} (\delta)] - \ln (\delta-1) - \ln G_t - \ln NX_t \quad (29)$$

The Equation (29) will be used to explain the rapid rise in the sales of housing in China. So, from Equation (29), the effect mechanism of energy consumption on equilibrium housing sales can be derived:

$$\frac{\partial \ln h_t}{\partial \ln (EC_t)} = a+1 \quad (30)$$

So, an important hypotheses stem from Equation (30):

Hypothesis: Energy consumption is positively related with housing sales in

China.

3. Data Description and Econometric Methodology

3.1. Data

In order to test the effect of energy consumption on housing sales above, we utilized data from China and conduct this analysis at the province level. However, we exclude the data from Tibet province, because of the problem of data missing. Hence, there are 30 provinces in our sample. Panel data from 2004 to 2015 were obtained from the China statistical yearbook from 2005-2016 and the China Stock Market & Accounting Research (CSMAR) Database and EPS database. The spatial distribution of housing sales of China in 2004 and 2015 are listed in **Figure 1** and **Figure 2**.

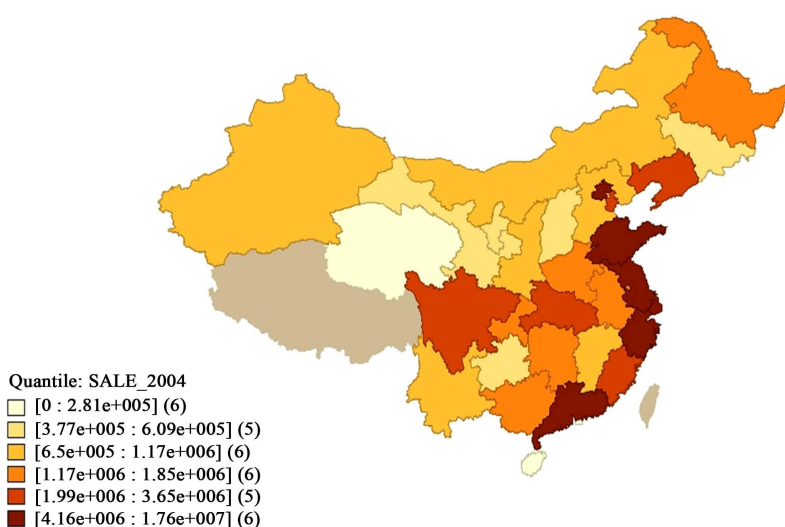


Figure 1. Hot bitmap of housing sales of China in 2004.

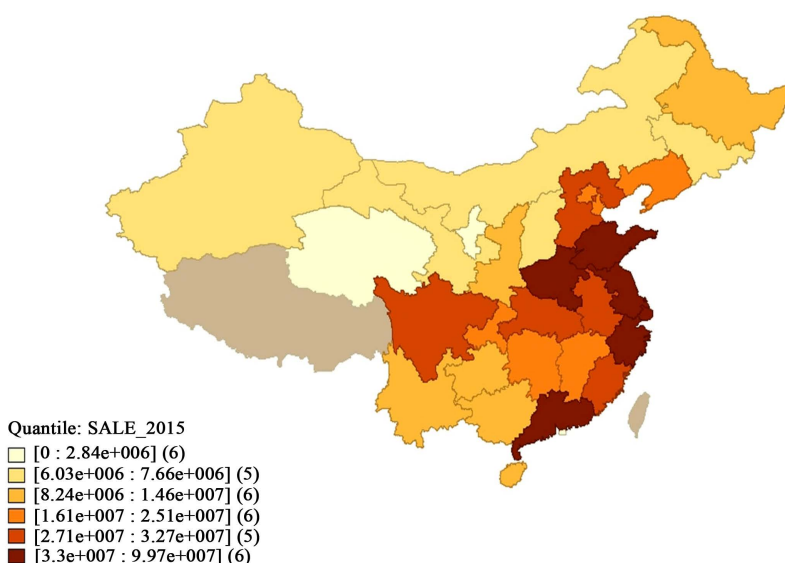


Figure 2. Hot bitmap of housing sales of China in 2015.

Similarly, the spatial distribution of coal consumption of China in 2004 and 2015 are listed in **Figure 3** and **Figure 4**.

The description and definition of variables are shown in **Table 1**.

The statistical description is demonstrated in **Table 2**.

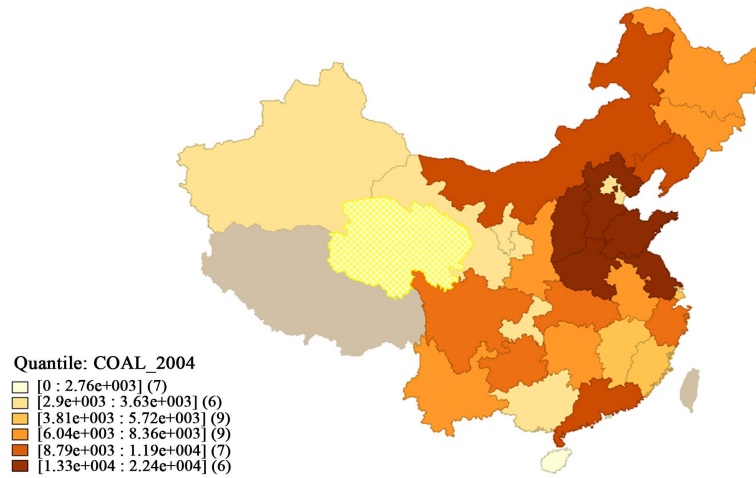


Figure 3. Hot bitmap of coal consumption of China in 2004.

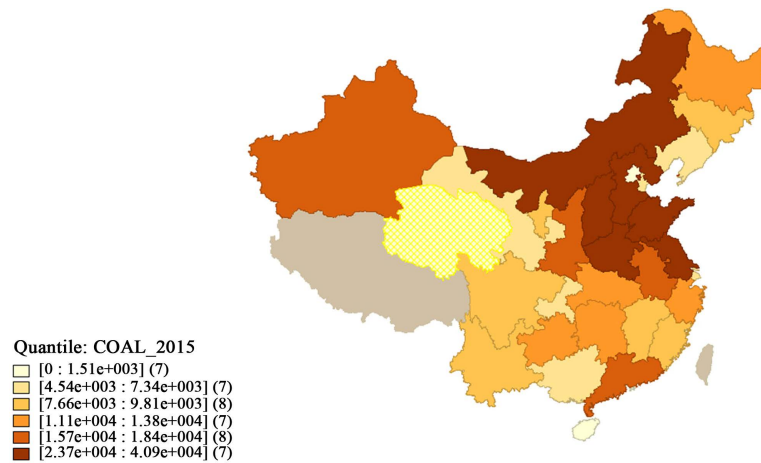


Figure 4. Hot bitmap of coal consumption of China in 2015.

Table 1. Mnemonic and variable definition.

Variable	Mnemonic	Definition	Expected direction
housing sales	ltsale	$ltsale = \ln(\text{housing sales})$	
coal consumption	lcoal	$lcoal = \ln(\text{coal consumption})$	+
average price of house	laprice	$laprice = \ln(\text{average price of house})$	+
employment in housing sector	lem	$lem = \ln(em)$	+
industrialization	lur	$lur = \ln(\text{non-agricultural output/GDP})$	+
net export	lnx	$lnx = \ln(\text{export-import})$	-
local government expenditure	lg	$lg = \ln(\text{local government expenditure})$	-

Table 2. Variables descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
lsale	360	15.78512	1.24224	11.68179	18.41741	-0.54273	2.904726
lcoal	360	9.066617	0.909592	5.786928	10.61954	-0.9167	4.337971
laprice	360	10.20024	0.668059	8.346405	11.58952	-0.14927	2.402243
lur	360	4.478663	0.070334	4.144832	4.600789	-0.80762	5.206171
lem	360	10.92285	0.753468	8.394347	12.34112	-0.79331	3.644049
lg	360	7.201438	0.881996	4.673856	9.189754	-0.44411	3.028859
lnx	360	6.56454	11.51134	-17.226	17.0883	-1.12129	2.387432

To describe the statistical characteristics among the variables, the scatter fitting figure is utilized. **Figure 5** depicts the scatter fitting plot between coal consumption and housing sales, **Figure 6** depicts the scatter fitting plot between industrialization and housing sales, and **Figure 7** depicts the scatter fitting plot between housing prices and housing sales. They all demonstrate that housing sales, coal consumption, industrialization, and housing prices increase together respect to time.

3.2. Econometric Model Design and Specification

3.2.1. Panel unit Root Model

A standard individual ADF test was conducted on stationary panel data [10]. Following this line of analysis, we first test the unit roots of y_{it} to confirm the stationary properties for each variable. This was achieved by using the Im-Pesaran-Shin (IPS) test [11]. In order to verify the robustness of the sequence, we used IPS method to test the heterogeneity of panel unit root, the advantages of this method is not only consider the heterogeneous panels, but also consider the issues about serial correlation.

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{L=1}^p \beta_{iL} \Delta y_{i,t-L} + z'_{it} \gamma_i + \epsilon_{it}, \quad i = 1, 2, \dots, N; t = 1, 2, \dots, T \quad (31)$$

where, $y = \{\text{lsale}, \text{lcoal}, \text{laprice}, \text{lem}, \text{lur}, \text{lnx}\}$ is 5×1 dimensional vector, z'_{it} is a temporal trend term, γ_i is the coefficient vector, ϵ_{it} is the error term and satisfies the independent normal distribution.

3.2.2. Panel Data OLS Regression and Fixed Effect Model

Since the fixed effect regression comes from the OLS panel model, we firstly introduce the latter:

$$ltsale_{it} = x'_{it} \beta + z'_i \delta + \mu_i + \varepsilon_{it} \quad (i = 1, 2, \dots, n; t = 1, 2, \dots, T) \quad (32)$$

where, x_i is vector including the key variables (local, laprice, lur) and controlled variables (lg, lem, lnx); the observable random variable z_i represents the intercept term of individual heterogeneity such as customs, culture, location, etc., disturbance term is composited by $\mu_i + \varepsilon_{it}$, which is also called composite error term. Unobservable random variable μ_i represents the intercept term of individual heterogeneity, and ε_{it} is the perturbation term varying with the individual and time. It is generally assumed that ε_{it} is independent and identically

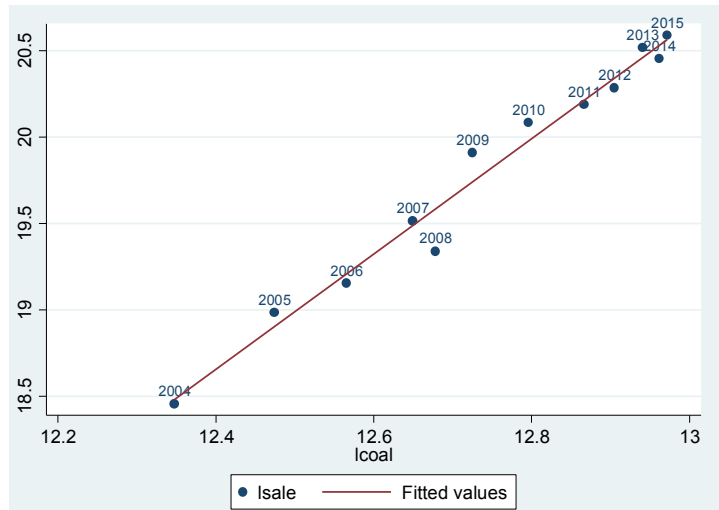


Figure 5. Scatter fitting plot between local and lsale.

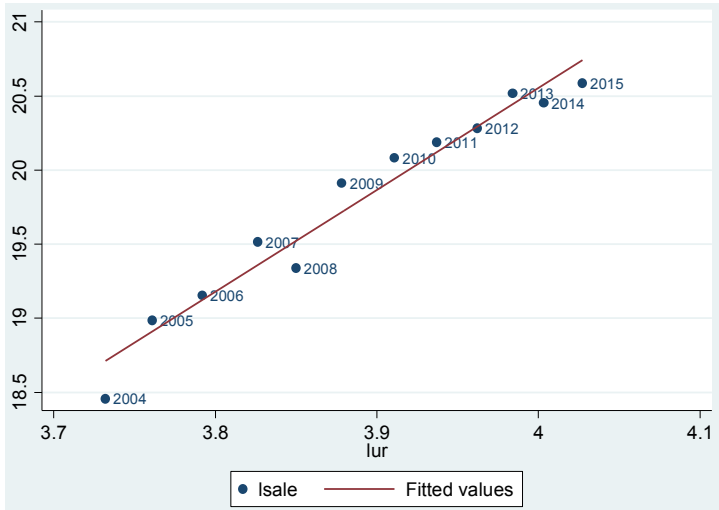


Figure 6. Scatter fitting plot between lur and lsale.

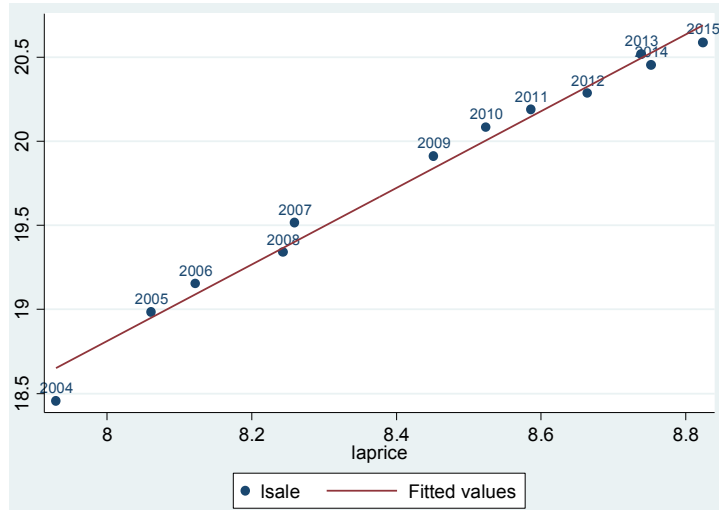


Figure 7. Scatter fitting plot between laprice and lsale.

distributed, and is not related to μ_i . The pooled OLS model and fixed effect model are based on (32). The pooled OLS regression assumes that all individuals have a consistent regression equation, and the model (33) is transferred as follows:

$$ltsale_{it} = \alpha + x'_{it}\beta + z'_i\delta + \varepsilon_{it} \quad (i = 1, 2, \dots, n; t = 1, 2, \dots, T) \quad (33)$$

For the fixed effect model, given the individual i , the mean value of the Equation (33) respect to time t is as below:

$$\overline{ltsale}_{it} = \overline{x'_{it}}\beta + z'_i\delta + \mu_i + \overline{\varepsilon_{it}} \quad (i = 1, 2, \dots, n; t = 1, 2, \dots, T) \quad (34)$$

Then, the Equation (32) minus the mean Equation (34), so we obtain:

$$ltsale_{it} - \overline{ltsale}_{it} = (x_{it} - \overline{x'_{it}})' \beta + (\varepsilon_{it} - \overline{\varepsilon_{it}}) \quad (35)$$

Next, we define $\widetilde{ltsale}_{it} = (ltsale_{it} - \overline{ltsale}_{it})$, $\widetilde{x}_{it} = (x_{it} - \overline{x'_{it}})$, $\widetilde{\varepsilon}_{it} = (\varepsilon_{it} - \overline{\varepsilon_{it}})$. We have:

$$\widetilde{ltsale}_{it} = \widetilde{x'_{it}} \beta + \widetilde{\varepsilon}_{it} \quad (36)$$

In (36), μ_i can be eliminated, so if $\widetilde{\varepsilon}_{it}$ is not correlated with \widetilde{x}_{it} , OLS can be used to estimate consistent estimates β .

3.2.3. Spatial Panel Data Econometric Model

In order to measure the spillover effect of housing sales, the spatial panel data econometric model generally can be expressed as [12] [13]:

$$y_{it} = \tau y_{i,t-1} + \rho w'_i y_t + d'_i X_i \delta + \mu_i + \gamma_i + \varepsilon_{it}$$

$$\varepsilon_{it} = \lambda m'_i \varepsilon_i + v_{it}$$

where, w'_i is the i th row in spatial weight matrix $W(i, j)$, $w'_i y_t = \sum_{j=1}^n w'_{ij} y_{jt}$, and w_{ij} is the element of the spatial weight matrix $W(i, j)$. $\rho w'_i y_t$ is the spatial lagged term; y is the dependent variable (ltsale), X is the vector of independent variables (local, laprice, lem, lex, lg, lur), μ_i is the individual effect among the provinces; γ_i is the time effect among the provinces; m'_i is the disturbing term at the i th row in spatial weight matrix.

If $\lambda = 0$ and $\delta = 0$, we will have the spatial autoregressive model. If $\tau = 0$ and $\delta = 0$, we will have the spatial autocorrelation model. If $\tau = \rho = 0$ and $\delta = 0$, we will have the spatial error model.

3.2.4. Spatial Autocorrelation and Moran Index

Spatial weight matrix is the requirement to use spatial econometric analysis. Based on the spatial distance between provinces and according to the spatial distribution of the variables, we construct the spatial weight matrix. The method to construct matrix is that if two provinces are adjacent, and the value of element in the spatial weight matrix is identical to 1. Otherwise, the value of element in the spatial weight matrix is identical to 0. Then through the Moran index, we could measure the spatial dependence of the spatial panel data. The Moran index is as follows [14]:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\left(\sum_{i=1}^n \sum_{j=1}^n \omega_{ij} \right) \sum_{i=1}^n (x_i - \bar{x})^2}$$

where $\bar{x} = \frac{1}{n} \sum_{j=1}^n x_j$, x_i is the value of the i th province, n is the number of province, ω_{ij} is the value of element in spatial weight matrix from the i th province to the j th province. Moran index ranges from $[-1, 1]$. If I is closer to 1, it means the stronger positive spatial correlation. If I is close to -1 , it means the negative spatial correlation is stronger. If I is closer to 0, it means spatial correlation does not exist. Moran index can be regarded as the coefficient of correlation between the spatial lag and the value of observation. If the observation value and the spatial lag are drawn scatter diagram, namely Moran scatterplot, the Moran index I is the slope of the regression line of the scatter.

4. Empirical Results

4.1. Unit Root Test

We use individual ADF test to identify the unit root process. The null hypothesis is that the variable is nonstationary. The results in **Table 3** show that *lur*, *lg* and *lem* are stationary at one percent significant level, and *ltsale*, *laprice*, and *lnx* are stationary at five percent significant level.

In terms of the IPS test, the null hypothesis is that the panel series are nonstationary. The test results are shown in **Table 4**. *ltsale*, *laprice*, *local*, *lur*, *lg*, and *lem* are stationary at one percent significant level, and *lnx* is stationary at five percent significant level.

Table 3. Individual ADF test results.

variable	t-bar	cv10	cv5	cv1	Z[t-bar]	P-value	length
<i>ltsale</i>	-2.098	-2.07	-2.15	-2.32	-1.923	0.027**	1
<i>lcoal</i>	-5.055	-2.07	-2.17	-2.34	-16.603	0.000***	2
<i>laprice</i>	-2.153	-2.07	-2.15	-2.32	-2.215	0.013**	0
<i>lur</i>	-2.24	-2.07	-2.17	-2.34	-2.589	0.005***	2
<i>lnx</i>	-2.106	-2.07	-2.17	-2.34	-1.92	0.027**	0
<i>lg</i>	-4.542	-2.07	-2.17	-2.34	-14.052	0.000***	2
<i>lem</i>	-2.274	-2.07	-2.17	-2.34	-2.759	0.003***	0

Note: *indicates 10% critical value, **indicates 5% critical value and ***indicates 1% critical value.

Table 4. IPS test results.

variable	t-bar	cv10	cv5	cv1	W[t-bar]	P-value	length
<i>ltsale</i>	-2.003	-1.69	-1.73	-1.82	-3.171	0.001***	3
<i>lcoal</i>	-2.54	-1.69	-1.74	-1.83	-5.847	0.000***	0
<i>laprice</i>	-2.05	-1.69	-1.73	-1.82	-3.463	0.000***	2
<i>lur</i>	-2.068	-1.69	-1.74	-1.83	-3.078	0.001***	1
<i>lnx</i>	-1.838	-1.690	-1.740	-1.830	-1.824	0.034**	1
<i>lg</i>	-1.965	-1.69	-1.74	-1.83	-2.572	0.005***	0
<i>lem</i>	-2.764	-2.330	-2.380	-2.480	-3.508	0.000***	0

Note: *indicates 10% critical value, **indicates 5% critical value and ***indicates 1% critical value.

4.2. Spatial Autocorrelation Test Results

According to the Moran index of housing sales from 2004 to 2015 in China, as shown in **Figure 8**, there is significant spatial autocorrelation in the sample, because the Moran index is greater than zero and less than one.

Additionally, the spatial distribution of Moran index of the housing sales of China in 2004 and 2015 are listed in **Figure 9** and **Figure 10**.

Similarly, the spatial distribution of Moran index of the coal consumption of China in 2004 and 2015 are listed in **Figure 11** and **Figure 12**.

Figures 9-12 all demonstrate that some provinces in deep red can reject the null hypothesis of non-spatial auto correlation, which is consistent with the global spatial auto correlation test result.

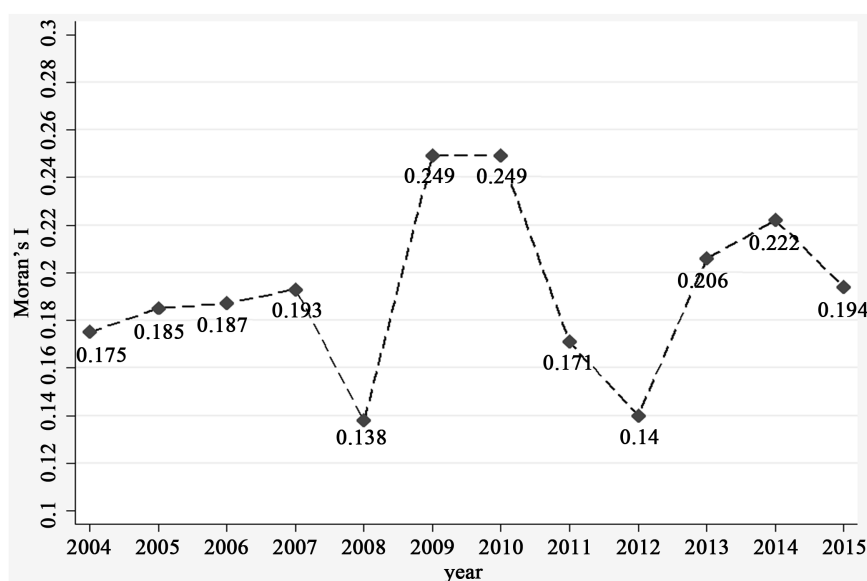


Figure 8. The Moran index of housing sales from 2004-2015.

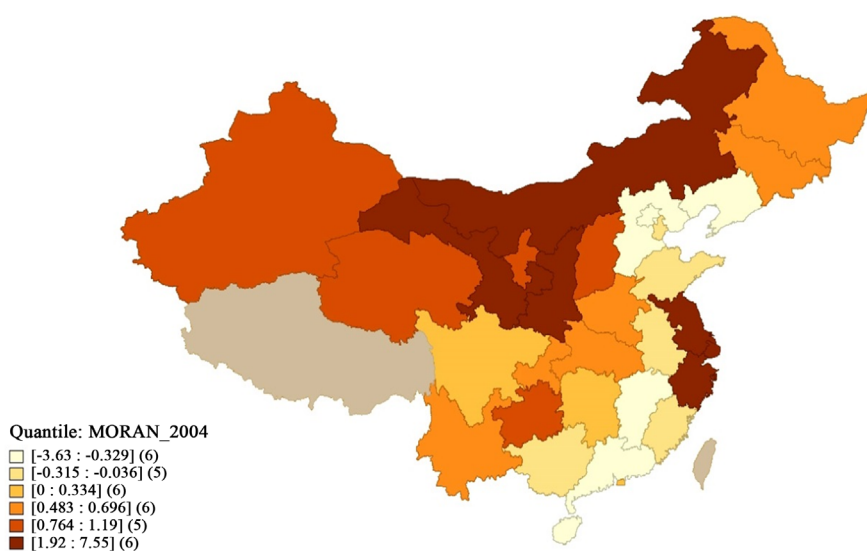


Figure 9. Hot bitmap of Moran index of housing sales in 2004.

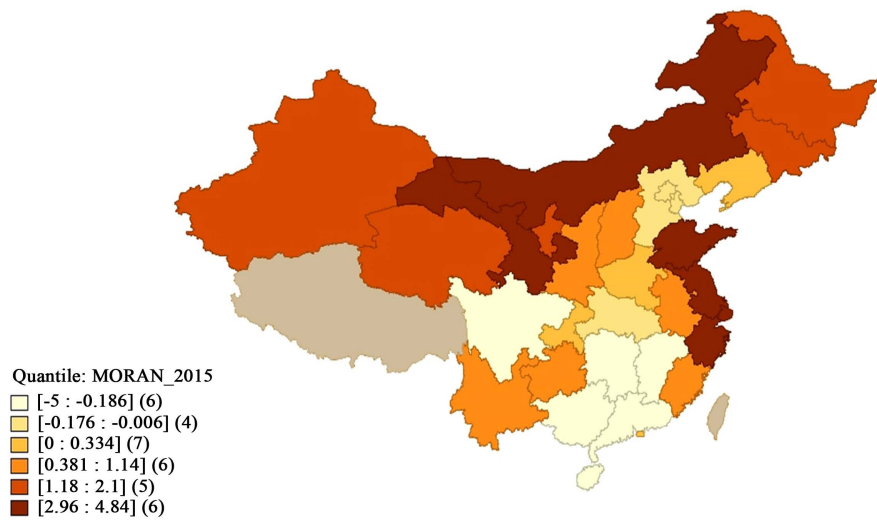


Figure 10. Hot bitmap of Moran index of housing sales in 2015.

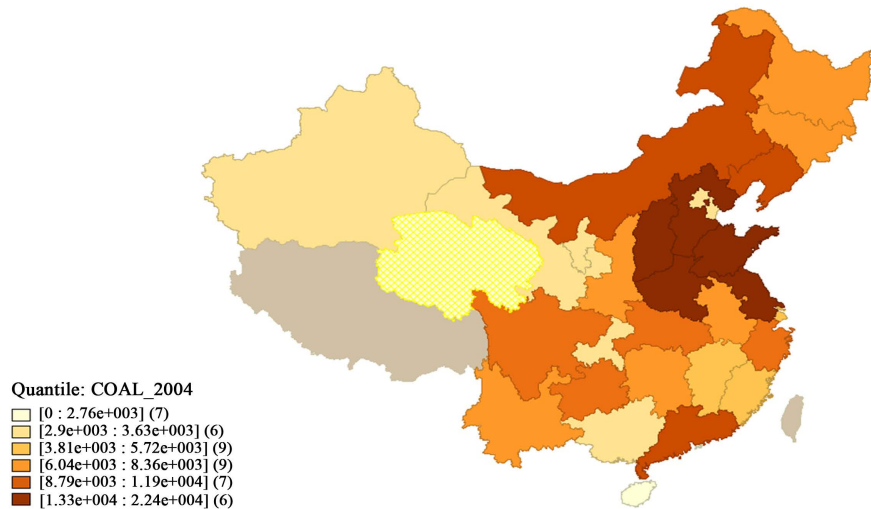


Figure 11. Hot bitmap of Moran index of coal consumption in 2004.

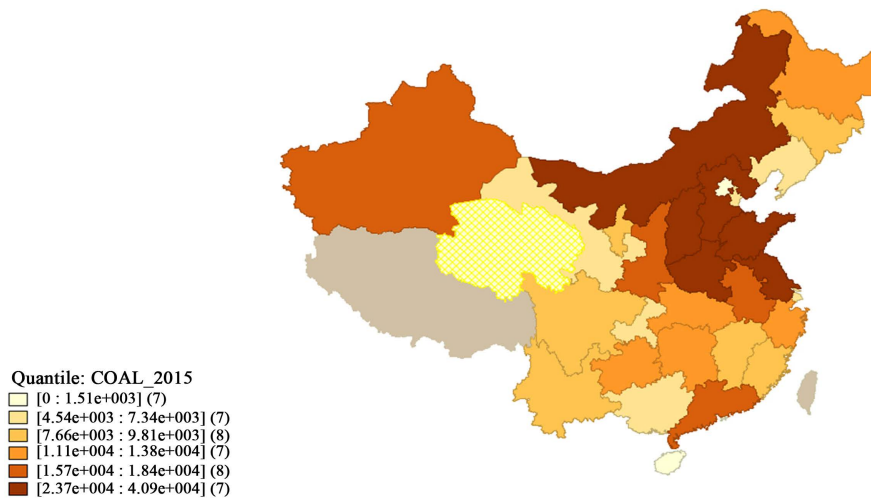


Figure 12. Hot bitmap of Moran index of coal consumption in 2015.

In addition, the Moran scatterplot of housing sales of China in 2004 and 2015 is listed in **Figure 13** and **Figure 14**. **Figure 13** and **Figure 14** show that, the spatial correlation Moran index of housing sales in China decrease from 0.203 (in 2004) to 0.196 (in 2015), which means that the global spatial auto correlation of housing sales in China becomes weaker respect to time.

Similarly, the Moran scatterplot of coal consumption of China in 2004 and 2015 is listed in **Figure 15** and **Figure 16**. **Figure 15** and **Figure 16** show that, the spatial correlation Moran index of coal consumption in China decrease from 0.203 (in 2004) to 0.196 (in 2015), which means that the global spatial auto correlation of coal consumption in China becomes weaker respect to time, too.

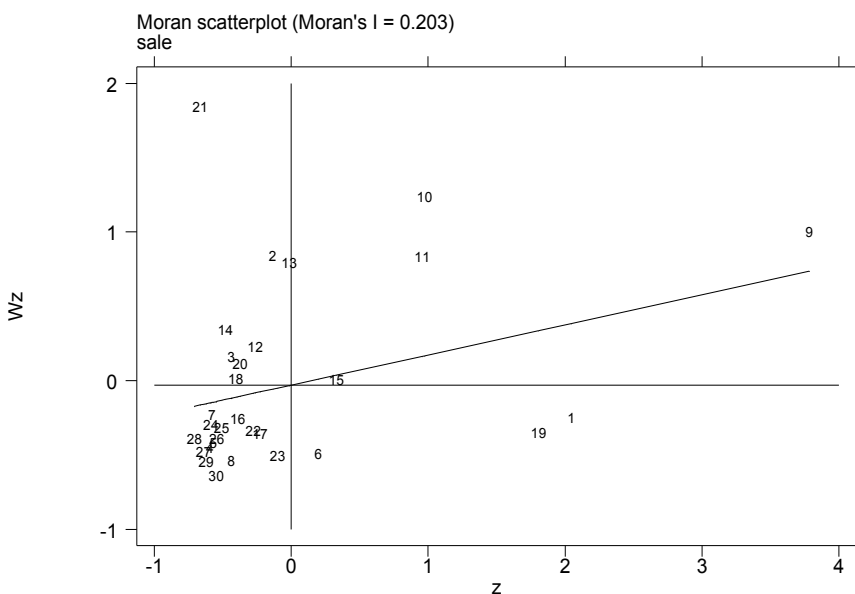


Figure 13. Moran scatterplot of housing sales of China in 2004.

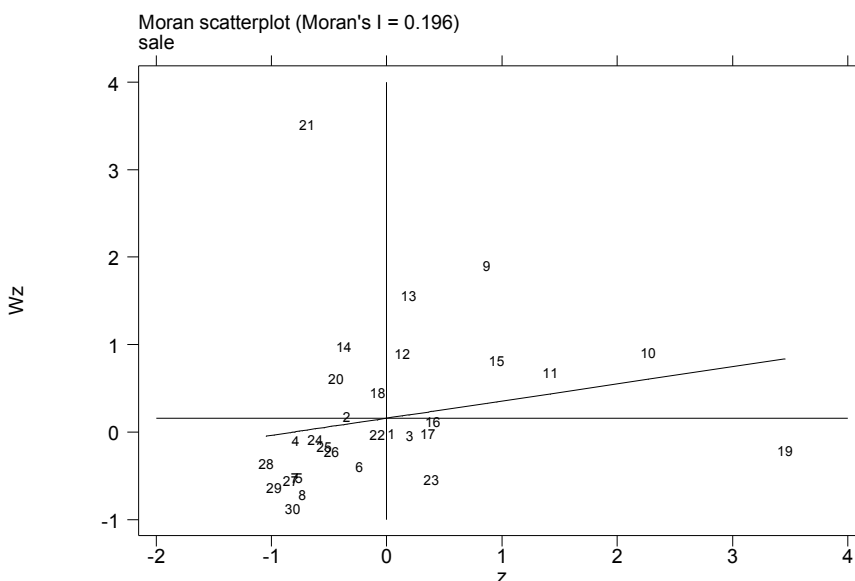


Figure 14. Moran scatterplot of housing sales of China in 2015.

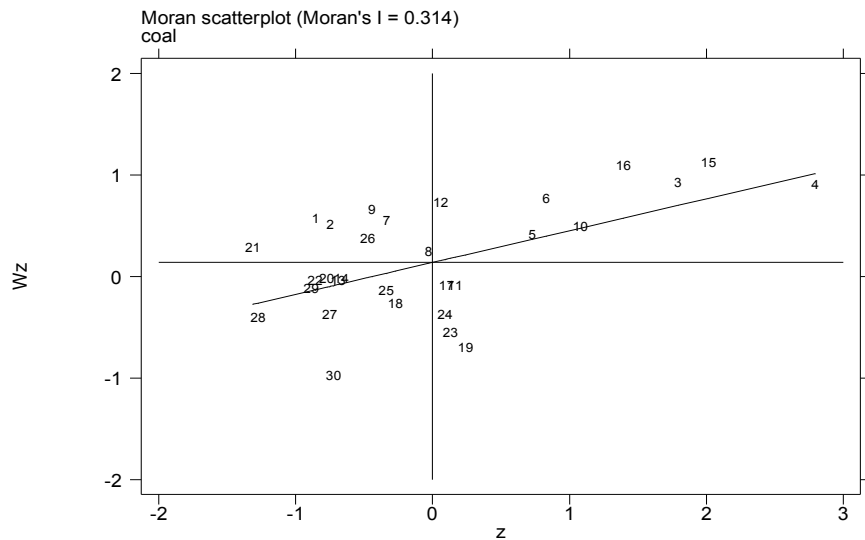


Figure 15. Moran scatterplot of coal consumption of China in 2004.

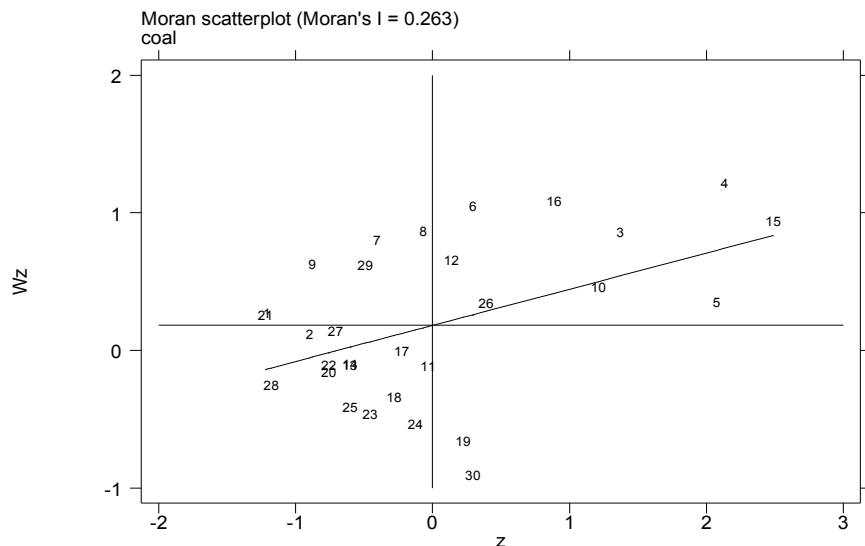


Figure 16. Moran scatterplot of coal consumption of China in 2015.

4.3. Regression Results

Since different models have different advantages and characteristics, and in order to ensure the robustness of the results, fixed effects panel model (PFE), spatial autoregression model (SAR), spatial error model (SEM), the spatial autocorrelation model (SAC) are utilized. In the SAR model, individual (SAR-IND) and individual-time (SAR-IT) these two types of model are considered, respectively.

Table 5 shows coal consumption is positively related to housing sales at one percent significant level in the PFE Model, SAR_FE Model, and, SAC_FE_IND Model. Meanwhile, the coefficient of coal consumption is positive and significant on five percent in SEM_FE Model and SAC_FE_IT Model. So, the hypothesis about the nexus between coal consumption and housing sales cannot be rejected.

Table 5. Regression results (ltsale as dependent variable).

	PFE Model	SAR_FE Model	SEM_FE Model	SAC_FE_IND Model	SAC_FE_IT Model
lcoal	0.410*** (-4.72)	0.324*** (-4.70)	0.170** (-2.07)	0.256*** (-4.83)	0.149** (-2.47)
laprice	1.205*** (-10.32)	0.569*** (-5.36)	1.274*** (-12.33)	0.201** (-2.30)	0.621*** (-4.77)
lur	4.412*** (-5.16)	4.371*** (-6.49)	1.697** (-2.50)	4.192*** (-6.78)	3.002*** (-4.68)
lem	0.139* (-1.67)	0.349*** (-5.15)	0.425*** (-5.87)	0.292*** (-5.54)	0.572*** (-9.14)
lg	-0.069 (-0.71)	-0.257*** (-3.25)	-0.138* (-1.68)	-0.237*** (-3.77)	-0.214*** (-2.99)
lnx	-0.001 (-0.51)	-0.002 (-0.95)	-0.001 (-0.47)	-0.001 (-0.56)	0.001 (-0.32)
intercept	-21.004*** (-6.04)				
rho		0.486*** (-12.03)		0.749*** (-16.84)	0.311*** (-3.11)
lambda			0.574*** (-11.07)	-0.679*** (-5.80)	-0.391*** (-2.72)
sigma2_e		0.035*** (-13.24)	0.037*** (-12.95)	0.029*** (-11.23)	0.028*** (-12.99)
N	360	360	360	360	360
R ²	0.92	0.675	0.757	0.645	0.81

Notes: 1) t statistics in parentheses. 2) *indicates 10% critical value, **indicates 5% critical value and ***indicates 1% critical value.

Furthermore, the coefficient of housing prices is positive significant, which is consistent with the statement derived from Equation (10). Since Equation (10),

$$\text{we have } \frac{\partial h_{t+1}}{\partial p_{t+1}^h} = \frac{c_{t+1}(1-\alpha) \left[p_{t+1}^h - p_t^h (r_{t+1} + 1 - \gamma - p_{t+1}^h / p_t^h) \right]}{\alpha p_t^h (p_{t+1}^h)^2 (r_{t+1} + 1 - \gamma - p_{t+1}^h / p_t^h)^2} > 0. \text{ Actually, in}$$

China, the housing prices bubbles demonstrate inter-provincial spillover effect [15], urbanization [16], local government's land hoarding behavior [17], local governments' budget deficit [18], income rises [19] and monetary policy impact [20] have led to a strong demand for housing in urban China [21]. So, the housing sales would rise, which is consistent with the positive relationship between housing prices and housing sales.

5. Conclusions

To analyze the nexus between coal consumption and housing sales in China, an optimal dynamic general equilibrium model is setup including energy and

housing sector. The empirical results indicate housing sales is positively correlated with the energy consumption and is positively correlated with housing prices. That outcome is similar to what has been documented in previous studies conducted using national level data for European countries, such as Wales, Sweden and Holland. It is instructive that, during a period of rapid industrialization, energy is found to represent a crucial factor undergirding economic growth [22]. This suggests that housing sales in developing countries may require economic growth and so energy generation as necessary pre-condition for expansion.

Indeed recent decades have seen a decoupling of GDP growth and energy consumption at the metropolitan level [23]. Gains in energy efficiency and consumption in the sectoral composition of total output have allowed housing sales to grow at a slower pace than GDP. An upward trend in housing sales has been observed in China from 2004 to 2015, suggesting that ever-increasing housing sales are not an indispensable corollary of regional energy consumption. Some scholars suggest the Chinese government should impose the property tax to control the housing prices bubbles [24], but according our theoretical and empirical findings, the housing prices control means housing sales regulation. However, the first-tier city bubble may not burst due to the urbanization process [25], hence, the housing sales and housing prices in China both dramatically go up, recently.

Future research avenues include development of the continued variable optimal dynamic stochastic general equilibrium of the nexus among housing prices, energy consumption, and economic growth. This model would require an in-depth analysis of dynamic optimization of housing prices along with specially developed non-linear energy consumption function in China [26]. In addition, a similar empirical framework could be extended by using a spatial difference-in-difference panel econometric model [15]. This model would require an in-depth analysis of the institutional effect of regional energy policy on housing prices and housing sales [16]. Finally, natural experiment coverage could be conducted to examine the nexus among energy consumption, housing prices and housing sale after and prior to national energy policy between the control regional group and treatment regional group [17]. This strategy would enable researchers to investigate whether or not housing prices and housing sales are altered when energy intensity is improved [27].

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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