EKC Analysis and Decomposition of Influencing Factors in Building Energy Consumption of Three Municipalities in China

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Abstract. The acceleration of the urbanization process has brought new opportunities for China's development. With the rapid economic development and people's living standards improving, building energy consumption also showed a rigid growth trend. With the continuous improvement of the level of industrialization, industrial energy-saving potential declines. The construction industry to bear the task of energy-saving emission reduction will face more severe challenges. As the three municipalities of China, Beijing, Shanghai and Chongqing have significant radiation effects in the economy, urbanization level and construction industry development of the region. Therefore, it is of great significance to study the building energy consumption in the three regions with the change of urbanization level and the key factors. Based on the data of Beijing, Shanghai and Chongqing from 2001 to 2015, this paper attempts to find out whether the EKC curve of building energy consumption exists. At the same time, based on the results of the model, the data of the three regions are divided into three periods. The exponential decomposition method (LMDI) is used to find out the factors that have the greatest impact on the energy consumption of buildings in different stages. Moreover, analyzes the policy background of each stage and puts forward some policy suggestions on this basis.

1. Introduction
Urbanization is the inevitable trend of the development of human society and a sign of the progress of the human society. With the development of economy, the pace of urbanization is accelerating. The essence of urbanization is that the process of the development of social productive forces promotes the population, capital and other factors of production to centralize to the city. Some scholars point that the process of urbanization will cause a series of problems, such as traffic congestion, market competition, environmental pollution, the rapid increase of the industrial production and population etc. [1] This also leads the city to become concentrated...
area of carbon emissions. In fact, the relationship between urbanization and carbon emissions has been extensively studied. PARIKH et al [2] studies the cross-sectional data of 83 developing countries and concludes that urbanization has a significant positive correlation with carbon emissions. YORK et al [3] employ the data of 137 countries in 1995 to study the relationship between urbanization and carbon emissions and incorporates the quadratic items of urbanization variables in the model. The result verifies that there is a significant nonlinear relationship between urbanization and carbon emissions. Based on the panel data of 86 countries, a research by COLE [4] shows that urbanization has significant positive correlation with carbon emissions. FAN et al [5] argue that income levels have an impact on the relationship between urbanization and carbon emissions. They also divide sample data from 198 countries into groups in accordance with the World Bank's income standards. The conclusion is that the impact of urbanization on carbon emissions in low-income groups is positive, and such impact of other income groups is negative. Moreover, only the negative correlation in the high-income group countries is significant. The samples of 88 countries are divided into high, medium and low income groups by Maruotti, A [6], who argues that the urbanization of the high-income groups has a significant inhibitory effect on carbon emissions, while urbanization has a promoting effect on carbon emissions in the low-income countries.

At present, the urbanization process is developing rapidly in China. Joseph E. Stiglitz, the winner of the 2001 Nobel laureate in economics, notes that China's urbanization and the new technological revolution in the United States are the two major events affecting the development of mankind in the 21st century. This reflects the significant impact of China's urbanization on the economy and society. Some scholars have discussed the relationship between urbanization and carbon emissions in China. ZHANG et al [7] find that the effect of urbanization on carbon emissions in central China is greater than that in the eastern region. YANG et al [8] argue that the relationship between urbanization and carbon emissions in different regions is different, and the effect of urbanization on carbon emissions in developed areas is not obvious. LU et al [9] argue that urbanization contributes to Chinese carbon reduction and the contribution is more obvious in the western region. ZHAO et al [10] conclude that urbanization has a significant inhibitory effect on carbon emissions. Chen et al [11] find that urbanization can effectively reduce the level of carbon emissions by conducting a comparison analysis between the United States and China. However, some scholars have drawn different conclusions. ZHU et al [12] find that the investment and exports in the process of urbanization can lead to significant growth in carbon emissions. ZHOU et al [13] find a significant positive correlation between urbanization and carbon emissions. LIU et al [14] point out that urbanization is the main driving force of carbon emissions in China. In addition, some scholars believe that there is no linear relationship between urbanization and carbon emissions. WANG et al [15] find that urbanization has a significant positive effect on carbon emissions in the early period of urbanization and further development of urbanization will inhibit the increase in carbon emissions through studying the panel data of 9 countries. By employing the STIRPAT, HU et al [16] verify that the relationship between the urbanization and carbon emissions in China meets the EKC curve.

From the above research, it is found that most of the existing research focus on the relationship between urbanization and carbon emission while research about the relationship between urbanization and building energy consumption are obviously insufficient. Although
CHU and HU[17, 18] take account of the impact of urbanization on building energy consumption in the study of driving factors behind building energy consumption, they just regard the urbanization rate as one of the factors affecting the building energy consumption. What is the main factor of building energy consumption in China? Is the impact of urbanization on building energy consumption in different regions of China consistent? Are the effects of the different urbanization stages on building energy consumption the same? In order to solve these problems, this paper selects Beijing, Shanghai and Chongqing, which are the major municipalities of China, as the research area. Considering that these three regions have their own unique characteristics and close economic ties, this paper applies the SUR model to investigate the correlation between urbanization and the building energy consumption in these regions. On the basis, this paper expounds the energy consumption of buildings in three regions during different periods in order to find the influencing factors of building energy consumption in different urbanization stages of different regions.

2. EKC analysis of building energy consumption based on the SUR

2.1. Variables and regression methods

This paper investigates the existence of environmental Kuznets curve (EKC) in the building energy consumption of three cities by establishing the SUR model of building energy consumption and urbanization rate in Beijing, Shanghai and Chongqing. The energy consumption per people (E) in three cities is the dependent variable and the urbanization rate (U) is the independent variable. Considering that Beijing, Shanghai, and Chongqing are major municipalities in China and their economic relationship is very close even if the urbanization processes of these three cities are at different stages, this paper also introduces per capita GDP (G) and foreign trade dependence (T) as independent variables. Taking the three cities as the research objects, the influencing factors of building energy consumption are both relevant and different, so the unrelated regression (SUR) model has unique advantages. SUR is a system of equations consisting of a series of equations that can be estimated based on the information about the equations of the error vector, which is more efficient than a single equation.

2.2. Model settings

In this paper, taking the urbanization rate as the main feature, and per capita GDP, foreign trade dependence as independent variables, per capita building energy consumption as dependent variable, the following four models are established:

\[
\log(E_i) = \alpha + \beta_1 \log(U_i) + \beta_2 \log(U_i)^2 + \varepsilon_i \quad (1)
\]

\[
\log(E_i) = \alpha + \beta_1 \log(U_i) + \beta_2 \log(U_i)^2 + \beta_3 \log(G_i) + \varepsilon_i \quad (2)
\]

\[
\log(E_i) = \alpha + \beta_1 \log(U_i) + \beta_2 \log(U_i)^2 + \beta_3 \log(T_i) + \varepsilon_i \quad (3)
\]

\[
\log(E_i) = \alpha + \beta_1 \log(U_i) + \beta_2 \log(U_i)^2 + \beta_3 \log(G_i) + \beta_4 \log(T_i) + \varepsilon_i \quad (4)
\]

\(i = \text{Beijing, Shanghai, Chongqing}; \ t = 2001, ..., 2015.\)

2.3. Data sources

The urbanization rate, per capita GDP and dependence on foreign trade of three regions are from the "China Statistical Yearbook". The urbanization rate is the ratio of urban population to
the total population; the per capita GDP is the ratio of regional GDP to the total population; the
dependence of foreign trade is the ratio of regional total import and export to regional GDP.

Access to energy consumption per capita in the region: This method is based on the energy
balance sheet. There are significant differences on energy balance information among
statistical yearbook of different regions. For consistence, the China Energy Statistical
Yearbook is employed as a data source for building energy consumption. The calculation
formula of building energy consumption is as follows:

\[
\text{Building energy consumption} = \text{building energy consumption} - \text{transport energy}
\]
\[
\text{consumption} + \text{other building energy consumption correction}
\]

| Variable                  | statistics | Beijing     | Shanghai    | Chongqing   |
|---------------------------|------------|-------------|-------------|-------------|
| Building energy consumption | average    | 1781.532    | 914.563     | 331.548     |
|                           | maximum    | 2244.870    | 1289.991    | 579.369     |
|                           | Minimum    | 1229.138    | 566.484     | 168.240     |
| Per capita GDP            | average    | 64295.600   | 66405.600   | 23923.200   |
|                           | maximum    | 106497.000  | 103796.000  | 52321.000   |
|                           | Minimum    | 26998.000   | 32201.000   | 6219.000    |
| Urbanization rate         | average    | 0.837       | 0.853       | 0.499       |
|                           | maximum    | 0.865       | 0.896       | 0.609       |
|                           | Minimum    | 0.781       | 0.753       | 0.374       |
| Foreign trade dependence  | average    | 0.796       | 0.526       | 0.372       |
|                           | maximum    | 0.854       | 0.569       | 0.458       |
|                           | Minimum    | 0.746       | 0.475       | 0.259       |

2.4. Result

We first take the logarithm of the variables: per capita building energy consumption, per capita
GDP, urbanization rate, dependence on foreign trade. In order to avoid the "pseudo-regression"
of the time series data, the stationary sequence of the time series is tested, which is the basis for
ensuring that the variables satisfy the cointegration test. In this paper, we use ADF test to test
the unit root test. Through Eviews 9.0 software to get the following conclusions: The
\[
\log(T_u), [\log(U_u)]^2 \text{ and } \log(G_u) \text{ is smooth. Although the ADF statistic of } \log(T_u), \log(E_u)
\]
is significant at 1% level, the ADF statistic is passed at a 1% level after a first order difference.
Their horizontal sequences are not stable, but the first order difference is stationary, i.e. these
variables are first order single I (1).

By the result of the unit root test, the above variables satisfy the cointegration test condition.
In this paper, we use the Johansen method to test the covariance of variables. The statistical
results show that there is at least one cointegration vector at the 10% significance level,
indicating that there are cointegration relations. This paper uses Stata12.0 to test the
environmental Kuznets curve of building energy consumption. The test results are shown in Table 2.

**Table 2. EKC Analysis of Building Energy Consumption Based on SUR Model**

|                | sur1          | sur2          | sur3          | sur4          |
|----------------|---------------|---------------|---------------|---------------|
| (1) Per capita building energy consumption \( U_1 \) | -12.48***     | -20.97***     | -14.02**      | -16.88        |
|                | (10.55)       | (14.48)       | (17.50)       | (18.63)       |
| Urbanization rate | -42.25***     | -60.08***     | -45.97        | -47.35*       |
|                | (27.21)       | (34.12)       | (43.86)       | (45.85)       |
| Beijing        |               |               |               |               |
| Per capita GDP | 6.645***      | 4.276***      | 6.495***      | 2.715         |
|                | (0.985)       | (3.338)       | (1.525)       | (3.497)       |
| Foreign trade dependence | 0.8624        | 0.83687       | 0.8492        | 0.83694       |
|                | (0.872)       | (1.145)       |               |               |
| Constant term  |               |               |               |               |
| EKC inflection point | 0.00646***    | -0.927***     |               |               |
| Arrival year   | 2012          | 2005          | 2008          |               |
| Shanghai       |               |               |               |               |
| Per capita building energy consumption \( U_1 \) | -0.0635**     | 5.515***      | 4.805***      | -4.635***     |
|                | (3.509)       | (5.936)       | (3.326)       | (6.515)       |
| Urbanization rate | -19.661***    | -1.236***     | -4.202***     | -3.829*       |
|                | (9.199)       | (12.78)       | (8.825)       | (11.06)       |
| Per capita GDP | -0.249***     | 0.984***      |               |               |
|                | (0.292)       | (0.498)       |               |               |
| Foreign trade  | -1.147***     | -3.134***     |               |               |
|                | (0.427)       | (0.986)       |               |               |
| Constant term  | 7.062***      | 10.39***      | 6.699***      | -6.723        |
|                | (0.300)       | (3.730)       | (0.365)       | (6.780)       |
| EKC inflection point | 0.89472      | 0.8107        | 0.56451       | 0.54607       |
| Arrival year   | 2009          | 2004          |               |               |
| Chongqing      |               |               |               |               |
| Per capita building energy consumption \( U_1 \) | 6.500***      | 3.596         | 6.707***      | 2.667*        |
|                | 6.500***      | 3.596         | 6.707***      | 2.667         |

*Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1.
rate & (1.142) & (2.630) & (1.862) & (3.179) \\
The square of & 20.572*** & 1.624 & 2.675 & 4.376* \\
 & (0.789) & (1.116) & (1.205) & (1.459) \\
Per capita GDP & 0.319*** & 0.445** \\
 & (0.263) & (0.272) \\
Foreign trade & 0.0819*** & 0.0488* \\
 & (0.206) & (0.201) \\
Constant term & 8.971*** & 4.273 & 9.146*** & 2.550 \\
 & (0.401) & (3.878) & (0.858) & (4.190) \\
EKC inflection & 0.854704 & 0.33055 & 0.28548 & 0.7374 \\
 & not reached & not reached & \\
N & 15 & 15 & 15 & 15 \\
R-sq & 0.716 & 0.687 & 0.651 & 0.648 \\

Standard error parentheses 
* p<0.1, ** p<0.05, *** p<0.01

From the results of model 1 in Table 2, we can see that there are environmental Kuznets curves in Beijing, Shanghai and Chongqing. Beijing reached the "inflection point" in 2008 and 2012 and Shanghai reached the "inflection point" in 2009. Building energy consumption in both regions are reduced with the increase of urbanization rates now. Chongqing has not yet reached the "inflection point" by now. Actually the inflection point of building energy consumption in Chongqing will appear when the urbanization rate reaches 0.74 and 0.85. Per capita GDP is added in Model 2 added , which studies the impact of economic development on the energy consumption in these cities. Beijing, Shanghai and Chongqing are in different stages of urbanization process. The economic development speed and process are also in different status. From the results, there are EKC curves in Beijing and Shanghai and the two regions reached the curve "inflection point" at year 2005 and 2004 respectively. The peaks of the two regions were earlier than the results of Model 1. Beijing's per capita GDP has a positive impact on building energy consumption, which means the building energy consumption will increase with the economic growth. In contrast to Beijing, per capita GDP in Shanghai has a negative impact on building energy consumption, indicating that with the improvement of urban economic development level, building energy consumption will reduced. Model 3 incorporates the variable of dependence on foreign trade, investigating the impact of foreign trade on building energy consumption in three regions from the perspective of external factors. The results show that foreign trade dependence in Beijing and Chongqing have a positive impact on building energy consumption, while the impact on Shanghai's building energy consumption is negative. Only the results of the model in Shanghai are meaningful in model 3. Model 4 also incorporates two variables: per capita GDP and foreign trade dependency from external and internal perspective. At this time Shanghai reaches the peak year in advance while the peak of Chongqing has not yet reached. Per capita GDP has a negative effect on the building energy consumption in Beijing and Shanghai, while foreign trade has a positive effect in Beijing and Shanghai.
From the results of model 1, 2, 3 and 4, the significance index of model 1 is obviously better than other models and its $R^2$ is the largest. So the fitting effect is the best. EKC curve of Beijing, Shanghai is inverted "U" shape, and the EKC curve of Chongqing is "U" shape. After adding variables such as GDP per capita and foreign trade, the results of the study were affected, and the significance of some results was reduced or even untrustworthy. These phenomena may be related to the government to adjust the economic development of the policy measures taken. Beijing and Chongqing will be will lead to building energy consumption with the economic development, only Shanghai's economic factors on the building energy consumption has the effect of emission reduction. This shows that even in developed areas in China is also difficult to achieve the effect of reducing building energy consumption to improve the environment. Therefore, the government needs to increase the intensity of building energy management. That is to say, the EKC curve of building energy consumption is not set up automatically, but requires the government and the people to raise awareness of building energy consumption and take effective policy measures and more advanced energy-saving technologies.

3. Beijing, Shanghai and Chongqing building energy consumption factor decomposition

3.1. Research methods
The second section of this paper concludes that Beijing, Shanghai have reached the EKC curve inflection point in 2012 and 2009 respectively. This section divides construction energy consumption into three stages: 2001 to 2009, 2009 to 2012 and 2012 to 2015. This paper analyzes the influencing factors of building energy consumption in three regions, trying to find out the factor with greatest impact on building energy consumption in three regions.

At present, the index decomposition method applied in the field of energy is most popular. The basic idea of the index decomposition is to decompose the change value of the target variable into a combination of several factors, and then to identify the size of the contribution of each factor to the target variable change value, to find the maximum-contribution value. Considering the practicality, operability and other factors, this paper finally employs LMDI index decomposition to analyze the driving factors behind the building energy consumption in concerned regions.

3.2. Model establishment
According to the different types of buildings, the building energy consumption is divided into rural building energy consumption, urban residential building energy consumption, and urban public building energy consumption. At the same time, according to the results and analysis of Section 2, the diving factors of building energy consumption include population, economy, urbanization rate, construction area, human behavior and technology and policy. The equation built according to the "I = PAT" model is as follows:

$$E_1 = P \times \frac{P_1}{P} \times \frac{C_1}{P_1} \times \frac{E_1}{S_1 \times B \times C_1} \times B \times S_1$$  \hspace{1cm} (5)

$$E_2 = P \times \frac{P_2}{P} \times \frac{C_2}{P_2} \times \frac{E_2}{S_2 \times B \times C_2} \times B \times S_2$$  \hspace{1cm} (6)
\[ E_i = \frac{P_i}{P} \times \frac{C_i}{P} \times \frac{E_i}{S_i} \times B \times C_3 \times B \times S_3 \]  

(7)

\( E_1, E_2, E_3 \) represent the energy consumption of rural buildings, the energy consumption of urban residents, and the energy consumption of urban public buildings. \( P \) is the total population of the region, representing the population factor. \( \frac{P_1}{P}, \frac{P_2}{P}, \frac{P_3}{P} \) are the proportion of rural population, the proportion of urban population, the proportion of urban population, representing urbanization factors and denoted by \( U_1, U_2, U_3 \) respectively. \( \frac{C_1}{P}, \frac{C_2}{P}, \frac{C_3}{P} \) are the per capita disposable income in rural areas, the per capita disposable income of urban residents, the per capita disposable income of urban residents, representing the economic factors and denoted by \( T C_1, T C_2, T C_3 \).

\( E_1, E_2, E_3 \) are the energy efficiency of rural buildings, the comparable energy efficiency of urban residential buildings, the comparable energy efficiency of urban public buildings, denoted by \( A_1, A_2, A_3 \).

Building energy efficiency indicators can well reflect the characteristics of economic growth, technological progress, energy conservation policies and human behavior factors behind carbon emissions. Regional building energy efficiency represents the regional policy measures and technical level about building energy consumption in the exclusion of economic factors and human behavior factors. \( B \) is the human behavior factor. \( S_1, S_2, S_3 \) are the rural construction area, urban residential construction area, urban public construction area.

Energy consumption model is as follow:

\[ E = \sum E_i = \sum_{i=1}^{3} P_i U_i TC_i A_i B S_i \quad (i = 1, 2, 3) \]  

(8)

The decomposition of equation (5) is carried out based on LMDI decomposition method. In the time \([0, T]\), the building energy consumption changes from \( E^0 \) to \( E^T \), the change amount and the change proportion are \( \Delta E_{tot}, D_{tot} \). The decomposition forms are:

\[ \Delta E_{tot} = E^T - E^0 = \Delta E_p + \Delta E_u + \Delta E_{TC} + \Delta E_A + \Delta E_B + \Delta E_S + \Delta E_{\epsilon} \]  

(9)

\[ D_{tot} = \frac{E^T - E^0}{E^0} = D_p D_u D_{TC} D_A D_B D_S D_{\epsilon} \]  

(10)

\[ E_p(D_p), \Delta E_u(D_u), \Delta E_{TC}(D_{TC}), \Delta E_A(D_A), \Delta E_B(D_B), \Delta E_S(D_S), \Delta E_{\epsilon} \] represent the total population, urbanization, per capita disposable income, comparable energy efficiency, behavioral factors and the contribution of building area to changes in building energy consumption. \( \Delta E_{\epsilon}, D_{\epsilon} \) is the decomposition residual value. Applying the LMDI decomposition method to analyse the contribution rates, the results are as follows:

Addition:
\[ \Delta E_p = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{P^T}{P^0} \right) \]  

(11)

\[ \Delta E_u = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{U^T}{U^0} \right) \]  

(12)

\[ \Delta E_{TC} = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{TC^T}{TC^0} \right) \]  

(13)

\[ \Delta E_a = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{A^T}{A^0} \right) \]  

(14)

\[ \Delta E_b = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{B^T}{B^0} \right) \]  

(15)

\[ \Delta E_s = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln \left( \frac{S^T}{S^0} \right) \]  

(16)

Multiplication:

\[ D_p = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_p \right\} \]  

(17)

\[ D_u = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_u \right\} \]  

(18)

\[ D_a = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_a \right\} \]  

(19)

\[ D_{TC} = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_{TC} \right\} \]  

(20)

\[ D_b = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_b \right\} \]  

(21)

\[ D_s = \exp \left\{ \ln \left( \frac{E^T}{E^0} \right) \Delta E_s \right\} \]  

(22)
From the current research results it can be seen that human behavior can directly affect the per capita building energy consumption. It is assumed that per capita building energy consumption is proportional to human behavior, namely:

\[ B = KE \] (23)

The result are as follows:

\[ \Delta E_A = \sum_i \frac{E_i^r - E_i^0}{\ln E_i^r - \ln E_i^0} \ln \left( \frac{A_i^r / A_i^0}{S_i^r / S_i^0} \right) = \sum_i \frac{E_i^r - E_i^0}{\ln E_i^r - \ln E_i^0} \ln \left( \frac{E_i^r / E_i^0}{S_i^r / S_i^0} \right) \] (24)

\[ \Delta E_B = \sum_i \frac{E_i^r - E_i^0}{\ln E_i^r - \ln E_i^0} \ln \left( \frac{B_i^r / B_i^0}{S_i^r / S_i^0} \right) = \sum_i \frac{E_i^r - E_i^0}{\ln E_i^r - \ln E_i^0} \ln \left( \frac{E_i^r / E_i^0}{S_i^r / S_i^0} \right) \] (25)

The relevant data are collected from the "China Statistical Yearbook", "China Energy Statistical Yearbook" and the calculation results of Section 2.3.

3.3. Model results
By calculation, the results are shown in Table 3.

| Table 3. Regional Building Energy Decomposition Results |
|--------------------------------------------------------|
| area | years | building energy consumption change | population | Urbanization rate | Per capita disposable income | Building energy efficiency | Behavioral factors | construction area |
|------|-------|----------------------------------|------------|------------------|-----------------------------|--------------------------|-------------------|-----------------|
| Beijing | 2001~2009 | 1916.2 | 639.2 | 82.74 | 1804. | -3192 | 1916. | 671.21 |
| | 2009 | 1916.2 | 639.2 | 82.74 | 1804. | -3192 | 1916. | 671.21 |
| | 2009~2012 | -281.41 | 255.5 | 13.73 | 654.1 | -1225 | -281.4 | 301.66 |
| | 2012 | -281.41 | 255.5 | 13.73 | 654.1 | -1225 | -281.4 | 301.66 |
| | 2012~2015 | 291.38 | 226.7 | 2.456 | 1441. | -2294 | 291.3 | 624.53 |
| | 2015 | 291.38 | 226.7 | 2.456 | 1441. | -2294 | 291.3 | 624.53 |
| Shanghai | 2001~2009 | -481.04 | 485.1 | 485.1 | 485.1 | 485.1 | 485.1 | 485.1 |
| | 2009 | -481.04 | 485.1 | 485.1 | 485.1 | 485.1 | 485.1 | 485.1 |
| | 2009~2012 | 193.0 | 2158.8 | 2158.8 | 2158.8 | 2158.8 | 2158.8 | 2158.8 |
| | 2012 | 193.0 | 2158.8 | 2158.8 | 2158.8 | 2158.8 | 2158.8 | 2158.8 |
| | 2012~2015 | 2012~2015 | 134.06 | 35.61 | 134.06 | 35.61 | 134.06 | 35.61 |
| | 2015 | 134.06 | 35.61 | 134.06 | 35.61 | 134.06 | 35.61 | 134.06 |
| Chongqing | 2001~2009 | 539.53 | 582.4 | 539.53 | 582.4 | 539.53 | 582.4 | 539.53 |
| | 2009 | 539.53 | 582.4 | 539.53 | 582.4 | 539.53 | 582.4 | 539.53 |
| | 2009~2012 | 328.69 | 481.0 | 328.69 | 481.0 | 328.69 | 481.0 | 328.69 |
| | 2012 | 328.69 | 481.0 | 328.69 | 481.0 | 328.69 | 481.0 | 328.69 |
| | 2012~2015 | 2012~2015 | 43 | 35.19 | 43 | 35.19 | 43 | 35.19 |
|               | 2012~             | 2015       | 2015       | 2015       | 2015       | 2015       |
|---------------|-------------------|------------|------------|------------|------------|------------|
|               | area              | years      | Building   | Population | Urbanization | Per capita   | Building    | Behavioral  | Construction |
|               |                   |            | energy     | rate       |              | disposable   | energy      | factors     | area         |
|               |                   |            | consumption| change      |              | income       | efficiency  |            |              |
| Beijing       | 2001~             | 2009       | 1.418      | 1.343      | 1.039       | 2.296       | 0.230       | 2.418       | 1.362         |
|               | 2009~             | 2012       | -0.086     | 1.085      | 1.004       | 1.233       | 0.676       | 0.914       | 1.101         |
|               | 2012~             | 2015       | 0.098      | 0.778      | 0.997       | 0.203       | 2.691       | 0.724       | 0.501         |
| Shanghai      | 2001~             | 2009       | 2.029      | 1.325      | 3.494       | 2.229       | 0.061       | 3.028       | 1.582         |
|               | 2009~             | 2012       | -0.168     | 1.077      | 1.004       | 1.395       | 0.729       | 0.832       | 0.910         |
|               | 2012~             | 2015       | 0.056      | 1.015      | 0.988       | 1.317       | 0.990       | 1.056       | 0.765         |
| Chongqing     | 2001~             | 2009       | 1.095      | 1.010      | 1.141       | 2.222       | 0.266       | 2.095       | 1.457         |
|               | 2009~             | 2012       | 0.318      | 1.030      | 1.051       | 1.499       | 0.548       | 1.318       | 1.134         |
|               | 2012~             | 2015       | 0.227      | 1.024      | 1.027       | 1.240       | 0.825       | 1.227       | 0.925         |
From the results in Table 3, Fig. 1 and Fig. 2, it can be seen that the effects of different variables on building energy consumption in different regions are different in different periods.

4. Analysis on the Trend of Building Energy Consumption in Beijing, Shanghai and Chongqing

From the results of Beijing, Shanghai and Chongqing, it can be found that the impact of building energy efficiency on building energy consumption are all negative, indicating that energy conservation policies and technologies are the main drivers of building energy consumption reduction. At the same time, changes in building energy consumption are also consistent with China's various industrial policies and environmental policies. The main influencing factors include the rise of heavy industry after 2000, the implementation of energy saving and emission reduction policies, the holding of the 2008 Olympic Games and the
economic stimulus plan after the global financial crisis. The year of 2006 - 2008 is Chinese "Eleventh Five - Year Plan" period and also the preparation and holding period of the Beijing Olympic Games. The "Eleventh Five-Year Plan" and the successful hosting of the Green Olympics proposed a resource-saving and environment-friendly society. The "Eleventh Five-Year" period also proposed and developed detailed energy-saving emission reduction measures. Under the influence of these policies, Chinese economic development began to focus on green development and low-carbon development. A series of economic stimulus plans were implemented in China due to 2008 global financial crisis, so some pollution-intensive industries obtained development opportunities. However, the effect of a series of stringent environmental regulation policies taken after 2005 became evident after 2009. The incentive effect of the economic stimulus policies taken after 2008 gradually appeared after 2012. These indicates that the implementation of relevant policies on the impact of building energy consumption has a certain time lag.

The per capita disposable income is the main driving factor of increasing building energy consumption in these cities. However, its effect on building energy consumption is weakening with time. Prior to 2009, the impact coefficient of per capita disposable income on building energy consumption reached a couple of points and declined after 2009. With the largest decline, the impact coefficient of the per capita disposable income on building energy consumption in Beijing is only 0.203 between 2012 and 2015. The impact coefficient in Shanghai is 1.317, which is the highest among these cities. It can be seen that with the regional economic growth and social progress, the impact of economic factors on the building energy consumption decreased year by year but stay positive. This also confirms that building energy consumption can not be effectively reduced only by economic development. Contrary to the effect of per capita disposable income, the impact of building energy efficiency on building energy consumption has been negative all the time and the coefficient of influence has increased over time. It can be seen that the government's energy-saving emission reduction policies and building energy-saving technologies are key factors in reducing building energy consumption. Building energy consumption reduction is a kind of public product. A single factor does not have enough power to reduce emissions, so reducing the building energy consumption must be involved in government departments. The impact of building energy efficiency and per capita disposable income on building energy consumption is shown in Figure 3.
The impact of population factors in Beijing and Shanghai on building energy consumption declined year by year, while the impact of the population factors of Chongqing on building energy consumption increased year by year before 2012 and then remained stable. It can be seen that building energy consumption doesn’t grow with the growth of population in Beijing and Shanghai but the population effect of Chongqing is still relatively obvious. The impact of the proportion of urban population on building energy consumption also shows a decreasing trend year by year. In Shanghai, a highly developed city in China, the building energy consumption even decreased with the increase of urbanization rate after 2012. In Beijing, the impact of urbanization on building energy consumption is also close to zero. This also confirms the conclusion that the urbanization rate of Section 2 has an EKC curve for building energy consumption and the time of inflection point. However, it can be seen from the results, the impact of urbanization on the effect of building energy consumption and intensity in the different level of economic development regions is different. Through the trend of Figure 4, we can see that with the development of society, the standard of living and the improvement of citizens' cultural quality, both the government and the citizens’ energy-saving awareness are constantly improving in the context of the government's strong advocacy of low-carbon lifestyles and the introduction of energy-saving buildings. The impact of improving building energy consumption of total population or urban population are declining, and even the impact of urbanization on the building energy consumption is negative effects, which is the future trend of social development.

Figure 3. Building energy efficiency and per capita disposable income on the impact of building energy trends
The impact of behavioral factors on building energy consumption is positive before 2009 and the impact is negative in 2009 ~ 2012. This change is related to the country's strong advocacy of energy-saving low-carbon lifestyle. Before 2008, the Olympic year, in order to run the Olympic Games, the government has made great efforts to control the environment. The most important thing is that people also formed an environmentally friendly low-carbon lifestyle. Moreover, after 2012, the role of behavioral factors on building energy consumption changed into a positive value. This shows that the government and relevant departments should continue to vigorously promote energy conservation policies awareness.

5. Conclusion

(1) Based on the data from 2001 to 2015 in Beijing, Shanghai and Chongqing, this paper attempts to verify the existence of the environmental Kuznets curve and the inflection point of the three places on building energy consumption. Four models were constructed by using the urbanization rate, per capita GDP and foreign trade dependence as independent variables. Finally, the results show that there are environment Kuznets curve of building energy consumption in Beijing, Shanghai and Chongqing. And the inflection point have been reached in Beijing and Shanghai while the EKC curve inflection point of Chongqing has not yet reached.

(2) According to the results of the SUR model, the data of Beijing, Shanghai and Chongqing are divided into three periods: 2001 ~ 2009, 2009 ~ 2012 and 2012 ~ 2015. The LMDI decomposition method is used to find out the factor which has the largest influence on building energy consumption. The results show that the per capita disposable income is the largest promoter of increasing building energy consumption and building energy’s efficiency factors are the largest contributors to reduce building energy consumption, which thus validates that the government’s energy-saving environmental protection policy, and building energy-saving technology are the main driving forces for the preservation of building energy.
(3) At the end of this paper, the trend and reason of building energy consumption are analyzed. It is finally found that the economy, behavior, population, construction area or urbanization factors are unable to spontaneously reduce the building energy consumption. This shows that the government's low-carbon environmental protection policies, low-carbon energy-saving lifestyle and awareness of the popularity must be implemented in order to form a role in reducing building energy consumption.

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