

The Study of Direct Energy Consumption of Urban Residents in China Based on the Modified IPAT- LMDI model

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Abstract

This paper firstly tries to build the information entropy of direct energy use of urban residents in China which can show the dynamic evolvement rules of energy consumption structure; Secondly it modifies and extends the IPAT equation which can clarify the direct impact of urban residents in China on energy,according to consumer lifestyle、 consumption pattern、 propensity to consume and income;Thirdly it builds the complete decomposition model of direct energy consumption of urban residents by LMDI (Logarithmic Mean Divisia Index) method ,at the same time amending and expanding one common mistake and limitations in the application of the model.

Key words: Direct Energy Use of Urban Residents; Information Entropy; The Modified IPAT- LMDI Model

1. Introduction

With the development of economy and urbanization, energy demand of urban residents is rising drastically, and the proportion of the total energy consumption is more and higher, so the impact of urban residents on energy consumption has become many scholars' studying focus.Lenzen,Weber (1998)and Perrels(2000)studied successively the impacts of household consumption patterns on energy demand with the input-output method in Australia、 the Federal Republic of Germany、 France and Holland; Bin and Dowlatabadi(2005) analyzed the effect of consumer lifestyle on energy demand;Yan Wang (2009) studied the total energy consumption of China's urban residents through the comparative analysis among different income groups, areas and residents consumption expenditure patterns respectively during 1995-2004 based on the input-output method;Qian Liu(2010) builded the consumption pressure population model to analyze the impact of household consumption on resources and environment based on the IPAT model, and thought that the pressure of household consumption had changed from a recessive factor to the dominant factor, and there were significant differences among different regions. Feng Ling (2011) tried to estimate the direct、 indirect energy consumption and carbon emissions of urban residents consumption which focused on the analysis of the influence factors of indirect energy consumption and carbon emissions.

Although the indirect energy consumption of residents is much more than the direct one, it is mainly affected by the industrial sector production technology and energy use efficiency,the direct energy consumption of residents is directly related to residents' life and affects the indirect one. Moreover,direct energy demand of residents is keeping rapid rise (Zhenyu Gao,2007;Ying Han,2010)and Therefore this paper will analyze the characters of direct energy consumption of China's urban residents building the Information entropy of energy consumption firstly; secondly try to modify the IPAT Equation considering consumer lifestyle,consumption patterns,the propensity to consumption and income, and furthermore build the complete decomposition model using the Logarithmic Mean Divisia Index method (Ang B.W,2004;20062007;Wood

Richard,2006),at the same time correcting some errors and explore its applications of this method.

2.Method

2.1 The Modified IPAT- LMDI Model

This paper tries to analyze the impact of residents direct energy consumption on resource and environment, which is necessary to modify and explore this model according to several index,The primary model of energy consumption is that formula 1:

$$E = P * (C / P) * EC \tag{1}$$

E is energy consumption of urban residents, P is the population of urban residents, C is urban residents consumption.

The modified IPAT- LMDI model is as follows:

$$E = \sum_i \frac{E_i}{E} * \frac{E}{C} * \frac{C}{R} * \frac{R}{P} * P = \sum_i ES * EC * APC * AR * P \tag{2}$$

The direct energy consumption of urban residents can be decomposed into five factors considering consumer lifestyle,consumption patterns,the propensity to consumption and income, so the factors on the right side of equation 2 are respectively energy consumption structure of Urban residents、 energy consumption intensity of urban residents、 average propensity to consumption、 the per capita disposable income and population of urban residents.

Secondly,the complete decomposition model of direct energy consumption of China's urban residents based on LMDI is that:

$$\Delta E_{eff}^d = E_i^d - E_0^d = \Delta ES_{eff} + \Delta EC_{eff} + \Delta APC_{eff} + \Delta AR_{eff} + \Delta P_{eff} \tag{3}$$

$$\Delta ES_{eff} = \sum \frac{(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t - ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)}{\ln(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t) - \ln(ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)} \times \ln\left(\frac{ES_i^t}{ES_i^0}\right) \tag{4}$$

$$\Delta EC_{eff} = \sum \frac{(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t - ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)}{\ln(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t) - \ln(ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)} \times \ln\left(\frac{EC_i^t}{EC_i^0}\right) \tag{5}$$

$$\Delta APC_{eff} = \sum \frac{(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t - ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)}{\ln(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t) - \ln(ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)} \times \ln\left(\frac{APC_i^t}{APC_i^0}\right) \tag{6}$$

$$\Delta AR_{eff} = \sum \frac{(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t - ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)}{\ln(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t) - \ln(ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)} \times \ln\left(\frac{AR_i^t}{AR_i^0}\right) \tag{7}$$

$$\Delta P_{eff} = \sum \frac{(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t - ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)}{\ln(ES_i^t EC_i^t APC_i^t AR_i^t P_i^t) - \ln(ES_i^0 EC_i^0 APC_i^0 AR_i^0 P_i^0)} \times \ln\left(\frac{P_i^t}{P_i^0}\right) \tag{8}$$

The left side index of formula 3 stands for the total change of direct energy consumption of urban residents, the formula (4)-(8) is the change of energy consumption due to one of the five factors when other four factors are constant.

There is a misunderstanding: many people think that the effect of one factor is positive or negative judged by the results of formula(4)-(8),if any one of formula(4)-(6)>0,he effect of the

homologous factor is positive, conversely, it is negative; in fact it is not true. For example the effect of energy consumption structure of urban residents is positive or negative should be judged by the results of formula (9), which can clarify the marginal change between the factor and the total change by the factor caused by formula (4):

$$\alpha_{ES} = \Delta ES_{eff} / \Delta ES \tag{9}$$

The effect of other factors also can be judged by the corresponding marginal coefficient.

2.2 The Information Entropy of direct energy use of urban residents

The information entropy is quantified on the disorder degree of a material or system movement (Haiqing Geng, 2004), which can reflect the change of structure, so this paper can analyze the dynamic evolution rules of energy consumption structure of direct energy use of urban residents in China, this method is that:

$$URECIE = -\sum_i^m \left(\frac{URE_i}{\sum_i URE_i} \right) \times \ln \left(\frac{URE_i}{\sum_i URE_i} \right) \tag{10}$$

URE_i is direct energy consumption of urban residents, $URECIE$ can clarify the structure change of direct energy consumption of urban residents. Another index called as DE (degree of equilibrium) can show the degree of homogeneity of residential energy consumption, it is that:

$$URECDE = -\left[\sum_i^m \left(\frac{URE_i}{\sum_i URE_i} \right) \times \ln \left(\frac{URE_i}{\sum_i URE_i} \right) \right] / \ln m \tag{11}$$

The corresponding index is DD (Degree of Dominance) is that:

$$URECDD = 1 - URECDE$$

DD plus DE equals 1, m is 10 which is the kinds of energy consumption, so $URECDD$ can show the influence degree of one or several energy on residential energy consumption.

3. The Feature of Direct Energy Consumption of Urban Residents in China

The direct energy consumption of urban households in this paper is mainly caused by living and private transportation which doesn't contain public transportation energy consumption, different from other authors (Weber C, 2000; Bin Shui, 2005). The kinds of home energy use are coal, oil, coke, electricity, natural gas, liquefied petroleum gas, gas and heat including lighting, cooking, heating, gasoline and diesel can be used by automobile consumption.

The direct energy consumption of urban residents in China is rising rapidly from 41.92 mtce in 1983 to 273.94 mtce in 2010, the average annual growth rate is 6.71%, which is both higher than the direct energy use of national and rural residents. Compared with other departments, the direct energy use of urban residents is still higher than agriculture, hunting, forestry and fishing, construction, wholesale & retail trade, hotels & restaurants and other industries, but the result of the comparison between urban residents and transport activities, storage, Post & telecommunications about energy consumption is different before 1998, the first one is more, from 1999 until 2010 the second one begins to rise faster (shown fig.1).

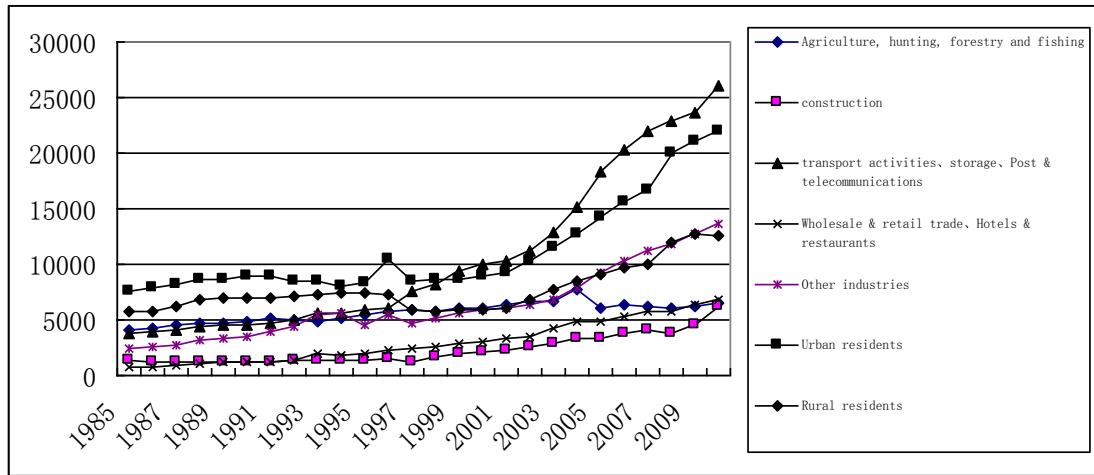


Fig.1 The energy consumption of sectors during 1983-2010

The per capita direct energy consumption level of China's urban residents has raised a lot from 188.24 kgce in 1983 to 409 kgce in 2010, which are 2 times of national residents and 3 times of rural residents. The structure of energy consumption of urban residents changes great from coals to electricity, natural gas and so on, the information entropy of direct energy use of urban residents improves rapidly from 0.43 to 1.77. *URECDE* adds from 0.19 to 0.77, which can show percent of some kinds of energy consumption changes in different directions, the structure of direct energy consumption of urban residents needs further optimization and upgrading (seen fig.2 and fig.3).

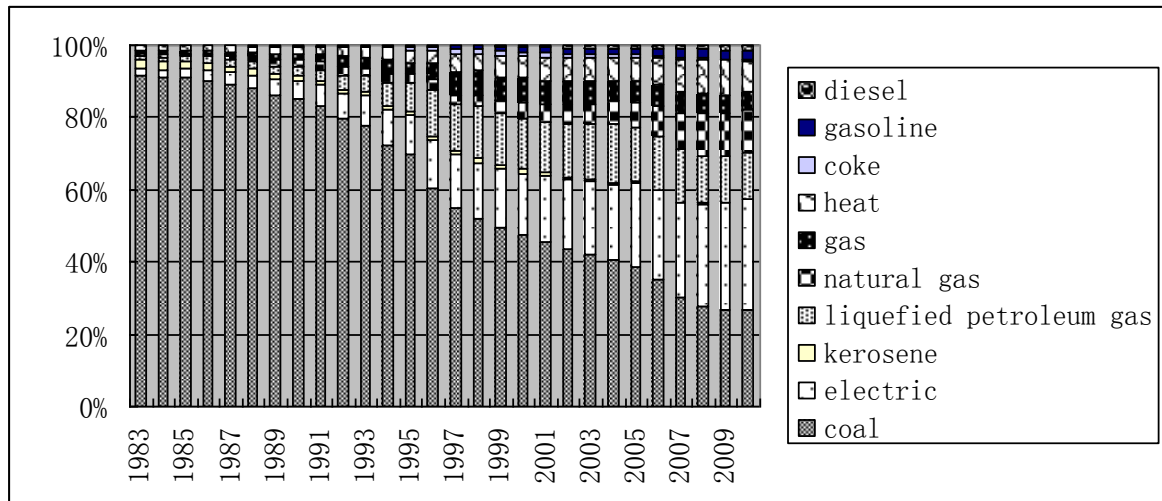


Fig.2 The structure of direct energy consumption of urban residents in China

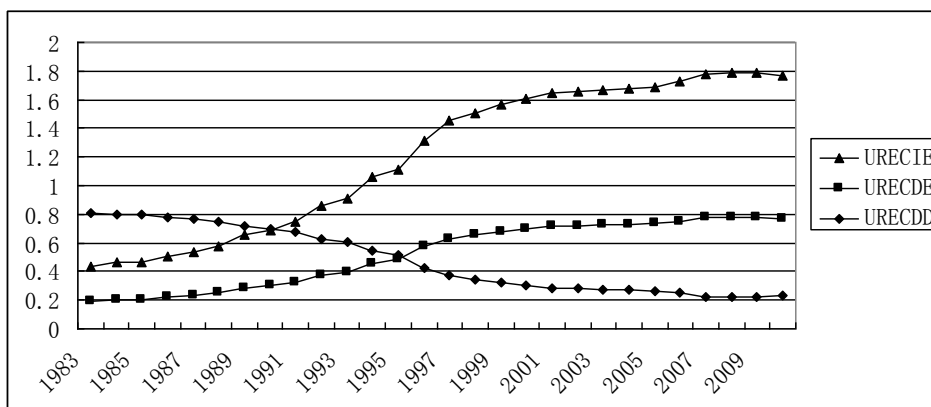


Fig.3 The dynamic change of the structure of direct energy consumption

4.The analysis of factors of direct energy consumption of urban residents

This paper tries to analyze the effect of five factors of direct energy consumption of urban residents based on the modified IPAT- LMDI model. The results reveal that the effect of five factors is positive, in other words, the direction of the change due to some factor is same as the factor. However, there are two direction of factors' change: energy consumption intensity of urban residents and average propensity to consumption both drop, so the decreasing-changes of energy consumption due to this two factors are respectively 9.4mtce and 1.4mtce; the per capita disposable income, population of urban residents and the change of energy consumption structure all rise, so the increasing-changes of energy consumption due to this three factors are respectively 14.7mtce, 4.67mtce and 0.0042mtce. Therefore we can know that the increasing-change of per capita disposable income is highest, the decreasing-change of energy consumption intensity of urban residents is more. Obviously with the income increase and urbanization the total direct energy consumption of urban residents in China will rise rapidly, in order to reduce the impact of urban residents in China on energy, it is necessary to strengthen the awareness of energy reduction, optimize the energy consumption structure and improve the efficiency of energy use of urban residents.

5. Conclusion

This paper firstly tries to build the information entropy of direct energy use of urban residents in China which can show the dynamic evolvement rules of energy consumption structure; Secondly it modifies and extends the IPAT equation which can clarify the impact of direct use of urban residents in China on energy, according to consumer lifestyle, consumption pattern, propensity to consume and income; Thirdly it builds the complete decomposition model of direct energy consumption of urban residents by LMDI (Logarithmic Mean Divisia Index) method, at the same time amending and expanding one common mistake and limitations in the application of the model. The conclusions are as follows:

The direct energy consumption of urban residents in China appears the fluctuation growth rate, the percent of living energy use is 90%, the percent of automobile consumption energy consumption is only 10%; the percent of the total energy consumption is 8%, higher than agriculture, hunting, forestry and fishing, construction, wholesale & retail trade, hotels & restaurants and other industries. The information entropy of direct energy use of urban residents still improves, which show the percent of different kinds of energy appears different directions. Two factors can the direct energy use drop, other three ones make it rise, the most effective

measures which can reduce the impact of urban residents in China on energy is to reduce energy consumption intensity, improve energy utilization.

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