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# *LMDI DM to Analyse the Changes and Causes of Energy Consumption Elasticity Coefficient*

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***Abstract:*** Economic development will inevitably bring about energy consumption(EC) and carbon emissions, resulting in environmental problems. China is a developing country and a responsible big country. It has both theoretical value and practical significance to give consideration to energy conservation and emission reduction and environmental protection while its economy is developing rapidly. This paper analyzes the changes and causes of EC elasticity coefficient based on LMDI decomposition method(DM), briefly analyzes the current situation of China's EC and EC elasticity coefficient, and puts forward LMDI DM; Taking province a as an example, the change and cause of EC elasticity coefficient in province a are analyzed by using LMDI DM.

## 1. Introduction

EC has increased year by year, bringing various problems. The massive use of fossil energy has caused a series of environmental and economic problems, and the problem of energy constraints has become increasingly serious, which has become one of the main factors restricting the harmonious development of economy and environment. Realizing energy conservation and consumption reduction and reducing the dependence of economic development on energy is a problem worthy of in-depth study. Therefore, this paper uses the LMDI DM to explore the reasons for the change of the elasticity coefficient of EC and find the main factors affecting EC, so as to provide a scientific theoretical basis for the formulation of energy conservation and emission reduction policies in the future.

Based on the LMDI DM, many scholars at home and abroad have studied and analyzed the changes and causes of the elastic coefficient of EC. Perkins J M aims to assess whether the differences in EC and insufficient energy intake in India's different socio-economic status (SES) have changed over time. The average dietary energy intake of each person in the family and whether the energy consumed by the family is lower than 80% of the recommended energy intake were calculated. Linear and relative risk regression models are used to estimate the relationship between Se and the average daily EC per person, as well as the relative risk of insufficient EC. Participants are nationally representative family samples. Results in rural households, there is a positive correlation between socio-economic status and energy input [1].

Based on the LMDI method, this paper establishes the EC decomposition model of a province, and analyzes the influencing factors on the change of EC elasticity coefficient of a province from 2000 to 2015. The conclusions are as follows: output scale effect and energy intensity effect are the two main factors affecting the change of EC in the province. The former promotes the growth of EC, while the latter inhibits the growth of EC. Population size effect, per capita living EC effect and urbanization effect all play a small role in promoting the growth of EC. Industrial structure effect is another reason to inhibit the growth of EC. Although the effect of EC structure has little impact on the change of EC, the gradual cleaning of EC structure plays a positive role in reducing CO2 emissions [2-3].

## 2. LMDI DM and EC Elasticity Coefficient

### 2.1. Current Situation of EC in China

In terms of total EC, in China's EC dominated by coal, the total EC has maintained an increasing trend since 88 years, with an increase of nearly 6 times. In terms of growth rate, the overall development shows a wavy pattern, with a negative value of -1.4% in 1981, rising from 0.53% in 1997 to 16.1% in 2004, with a huge growth rate. After reaching the highest peak of 16.1% in 2004, it gradually began to decline [4]. See Table 1 and figure 1 for the total EC and growth rate from 1988 to 2004.

*Table 1. Table of changes in total EC and growth rate*

| | 1988 | 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| Total(10000 tons of standard coal) | 97832 | 100532 | 100432 | 134321 | 135324 | 148065 | 148075 | 153534 | 214235 |
| Growth rate (%) | 5.1% | 4.3% | 5.2% | 5.6% | 2.7% | 0.6% | 4.4% | 5.2% | 14.7% |

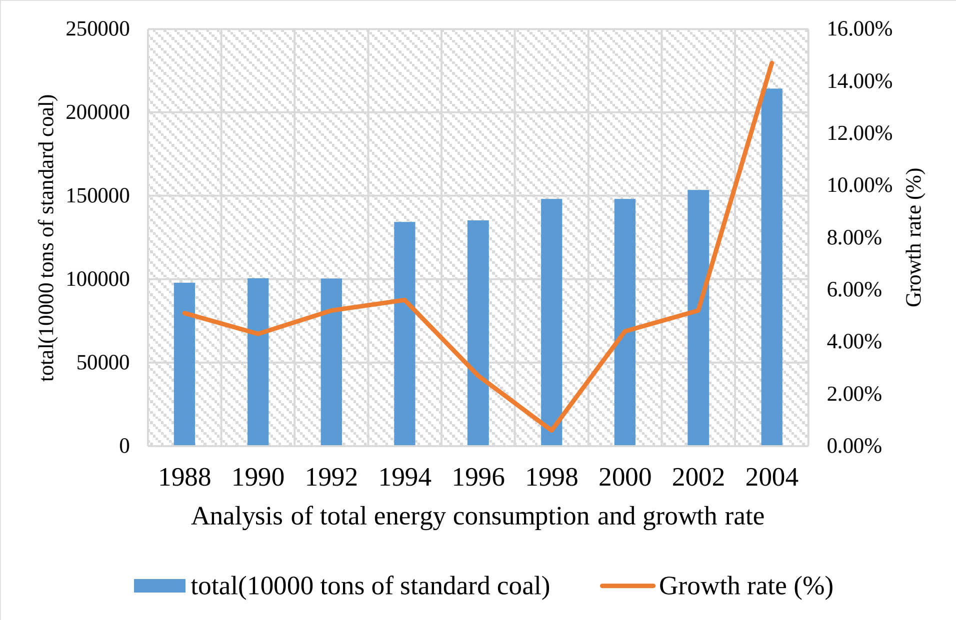


*Figure 1. Analysis of total EC and growth rate*

## 2.2. Elasticity Coefficient of EC

The elasticity coefficient of EC reflects the proportional relationship between the growth rate of EC and the growth rate of the national economy. If the elasticity coefficient of EC is less than 1, it means that the energy growth rate is less than the economic growth rate, that is, the EC per unit output in this year is lower than that in the previous year; If the elasticity coefficient is greater than 1, it means that the EC per unit output in this year is higher than that in the previous year; If the index is equal to 1, it indicates that the EC per unit output of this year is equal to that of the previous year. The elasticity coefficient of EC is used to study the proportional relationship between the growth of EC and economic growth, and to study the EC efficiency and economic development level of the economic system. Table 2 shows the relationship between China's economic growth and EC at different stages [5-6].

*Table 2. The relationship between China's economic growth and EC at different stages*

| Year | 1980-1985 | 1986-1990 | 1991-1995 | 1996-2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| GDP growth rate (%) | 10.8 | 7.9 | 12.1 | 8.2 | 7.4 | 8.3 | 9.1 |
| Growth rate of EC (%) | 4.8 | 5.3 | 5.8 | -0.1 | 3.5 | 9.8 | 13.1 |
| Elasticity coefficient of EC | 0.45 | 0.67 | 0.46 | -0.02 | 0.46 | 1.16 | 1.41 |

Energy elasticity coefficient and EC intensity can be used to reflect the relationship between economic growth and EC demand. From the long-term trend, the change of energy elasticity coefficient and EC intensity has a certain regularity. Generally speaking, in the initial stage of economic development, the growth rate of EC demand is higher than the economic growth rate. Later, with the improvement of economic development level, the growth rate of EC demand begins to decline and is lower than the economic growth rate, showing an inverted U-shaped change. However, in the short term, this relationship is not obvious, especially for China in the process of economic transformation [7-8].

## 2.3. LMDI DM

In this paper, LMDI method is selected to analyze the change of EC elasticity coefficient, because compared with other exponential DMs, the error term of LMDI method decomposition result is zero, and there will be no residual problem caused by other DMs. The LMDI method model is described below [9].

Let s be a total amount related to energy, assuming that there are n factors (recorded as x1, X2, X3,... Xn) that affect the change of s over time; Suppose the subscript I is a subcategory of the research target s, where si=s1, I, S2, I, S3, I Sn,i; Then V can be decomposed as follows:

$$S = \sum_i S_i = \sum_i S_{1,i} S_{2,i} S_{3,i} \ldots S_{n,i} \quad (1)$$

The subscript tot represents the change of total amount. According to the LMDI method, the general formula of the influence of the H-th factor on the right side of the equation can be obtained by corresponding the two decomposition forms to formula (1):

$$D_{xh} = \exp\left(\sum_i \frac{(S_i^T, S_i^0)/(InS_i^T - InS_i^0)}{(S^T, S^0)/(InS^T - InS^0)} \times In\left(\frac{x_{h,i}^T}{x_{h,i}^0}\right)\right) \quad (2)$$

$$\Delta S_{xh} = \sum_i L(S_i^T, S_i^0) In\left(\frac{x_{h,i}^T}{x_{h,i}^0}\right) \quad (3)$$

Where: l (a, b) = (a, b) / (LNA LNB). In the above operation process, if XH, i=0 is encountered, the zero value is replaced by a minimum value that does not affect the calculation result

The impact of EC structure on EC is small, so in order to simplify the calculation, the effect of energy structure is not considered in the comparative analysis of various regions across the country [10-11]. Based on this, the national EC change analysis model is constructed, as follows:

The total national end EC is expressed as:

$$F_2 = \sum_{ni} F_{ni,ind} + \sum_{nh} F_{nh,res} \quad (4)$$

$$F_2 = \sum_{ni} p_n G_n C_{ni} I_{ni} + \sum_{nh} p_n U_{nh} R_{nh} \quad (5)$$

Where: F2 is the total consumption of terminal energy in China; FNI, Ind are the EC of the I industry in the production sector of the nth region; Fnkres is the EC of residents from towns (k=1) and rural areas (k=2) in the nth region. PN -- the total population of the nth region at the end of the year; Gdpn -- the nth regional GDP; Gdpni -- the gross domestic product of the I industry in the nth region; PNH -- the total population of urban (k=1) and rural (k=2) at the end of the year in the nth region [12].

For the model shown in formula (5), according to the LMDI method, there are:

$$\Delta F_{TOT} = \Delta F_{IP} + \Delta F_G + \Delta F_I + \Delta F_{RP} + \Delta F_U + \Delta F_R \quad (6)$$

# 3. Analysis of EC Elasticity Coefficient Change based on LMDI DM

## 3.1. Data Source

In order to facilitate the following nationwide comparative analysis, this paper selects the time series of national end EC from 2000 to 2015 as the research object. Due to the lack of relevant data in Tibet, Hong Kong, Macao and Taiwan, this paper only considers 30 regions in the country. In order to ensure the accuracy of the data, the production department in this paper is divided into three industries. In addition, due to the increasing domestic EC of residents, it has become a part that can not be ignored, so it is also included in the calculation as a department.

The total economic output of each region is expressed by the GDP of each region, and the output of each department is expressed by the industrial added value. In order to eliminate the influence of price factors, the unit is 100 million yuan at the constant price of 1997. The final EC data of each region are from the regional energy balance table (physical quantity) in the China energy statistical yearbook over the years, and are converted according to the energy conversion coefficient of standard coal in the appendix of the statistical yearbook.

## 3.2. Results and Analysis

Analysis of influencing factors of EC change calculate the effect of influencing factors of EC change in province a according to formula (1) - (6). Table 3 shows the decomposition results of influencing factors of changes in EC in province a from 2005 to 2015, and table 4 shows the contribution rate (%) of various driving factors to changes in EC in province a from 2005 to 2015.

*Table 3. Influencing factors of changes in EC in province a (10000 tons of standard coal)*

| Particular year | ΔEIP | ΔEQ | ΔES | ΔEI | ΔEIM | ΔERP | ΔEU | ΔER | ΔERM | ΔETOT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2005-2006 | 44.6 | 1237.4 | 120.6 | -360.6 | 0.4 | 5.4 | 2.4 | 90.1 | 0.1 | 1140.2 |
| 2006-2007 | 50.5 | 1771.5 | 68.6 | -151.4 | -2.1 | 6.1 | 2.2 | 169.5 | 0.1 | 1914.8 |
| 2007-2008 | 36.9 | 2163.7 | 349.4 | -1206.0 | 1.3 | 4.3 | 9.6 | -76.1 | -0.1 | 1283.1 |
| 2008-2009 | 27.1 | 1218.3 | -44.6 | -395.6 | 0.3 | 2.9 | 3.4 | -7.5 | -10.7 | 804.2 |
| 2009-2010 | -13.4 | 2567.9 | 314.9 | 85.3 | 3.2 | -1.3 | 20.7 | 143.0 | 1.8 | 3120.2 |
| 2010-2011 | 11.4 | 2714.1 | 102.6 | -1016.2 | 1.1 | 1.1 | 23.5 | 91.0 | 0.1 | 1928.6 |
| 2011-2012 | -37.8 | 1791.1 | -236.5 | -158.3 | 1.1 | -3.8 | 18.9 | 156.9 | 1.1 | 1531.6 |
| 2012-2013 | -25.8 | 1492.4 | -329.4 | -1814.7 | -1.6 | -2.7 | 9.8 | -6.6 | -0.1 | -678.7 |
| 2013-2014 | 23.6 | 793.1 | -191.5 | -537.4 | 0.0 | 2.5 | 7.7 | 100.0 | 0.2 | 198.1 |
| 2014-2015 | -54.9 | 78.6 | -964.7 | -613.1 | -0.7 | -6.3 | 4.2 | 119.3 | 0.2 | -1437.8 |

From table 3 and table 4, it can be seen that the effects of various influencing factors on the changes of EC in the province from 2000 to 2015 are significantly different. It is mainly divided into three categories: positive promotion effect (population scale effect, output scale effect, urbanization effect, per capita living EC effect), negative inhibition effect (industrial structure effect, energy intensity effect), and almost no effect (EC structure effect). The two main influencing factors are output scale effect in positive promotion and energy intensity effect in negative inhibition. In addition, compared with other studies, the effect of industrial structure on all regions of the country is positive promotion, and the effect of industrial structure in this paper is negative inhibition, which shows that the adjustment of industrial structure in province a has begun to play a role in recent years.

*Table 4. Contribution rate of each driving factor to the change of EC in province a (%)*

| Particular year | ΔEIP | ΔEQ | ΔES | ΔEI | ΔEIM | ΔERP | ΔEU | ΔER | ΔERM | ΔETOT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2005-2006 | 3.9 | 108.5 | 10.6 | -31.6 | 0.0 | 0.5 | 0.2 | 7.9 | 0.0 | 100.0 |
| 2006-2007 | 2.6 | 92.5 | 3.6 | -7.9 | -0.1 | 0.3 | 0.1 | 8.9 | 0.0 | 100.0 |
| 2007-2008 | 2.9 | 168.6 | 27.2 | -94.0 | 0.1 | 0.3 | 0.7 | -5.9 | 0.0 | 100.0 |
| 2008-2009 | 3.4 | 151.5 | -5.5 | -49.2 | 0.0 | 0.4 | 0.4 | -0.9 | -1.3 | 100.0 |
| 2009-2010 | -0.4 | 82.3 | 10.1 | 2.7 | 0.1 | 0.0 | 0.7 | 4.6 | 0.1 | 100.0 |
| 2010-2011 | 0.6 | 140.7 | 5.3 | -52.7 | 0.1 | 0.1 | 1.2 | 4.7 | 0.0 | 100.0 |
| 2011-2012 | -2.5 | 116.9 | -15.4 | -10.3 | 0.1 | -0.2 | 1.2 | 10.2 | 0.1 | 100.0 |
| 2012-2013 | -3.8 | 219.9 | -48.5 | -267.4 | -0.2 | -0.4 | 1.4 | -1.0 | 0.0 | 100.0 |
| 2013-2014 | 11.9 | 400.4 | -96.7 | -271.3 | 0.0 | 1.3 | 3.9 | 50.5 | 0.1 | 100.0 |
| 2014-2015 | -3.8 | 5.5 | -67.1 | -42.6 | 0.0 | -0.4 | 0.3 | 8.3 | 0.0 | 100.0 |

## 4. Analysis on the Change of Elasticity Coefficient of EC and its Causes

Output scale effect: output scale effect is the main reason to promote the growth of EC in a province, and has been promoting the growth of EC. From 2002 to 2015, the contribution rate of output scale effect is basically higher than that of energy intensity effect. Energy intensity effect: from 2000 to 2015, the energy intensity of province a showed a downward trend as a whole, but there will be small fluctuations in some years. For example, in 2000, 2005 and 2010, the energy intensity of province a increased slightly compared with the previous year. In recent years, the energy intensity effect has promoted the growth of EC, but in general, the energy intensity effect has a restraining effect on the growth of EC and is the most important factor in restraining EC. The technological level of the province continues to improve, which plays a positive role in reducing EC.

Population scale effect: population growth plays a promoting role in both production and consumption and residents' living consumption, but the role is small. The change in EC caused by it accounts for 2.1% of the change in EC. The change of population scale effect is mainly divided into two stages: Taking 2009 as the time point, the population scale effect has promoted the growth of EC before, and the proportion is relatively high; After that, the contribution to the growth of EC fluctuated, either promoting growth or inhibiting growth. This is mainly due to the continuous growth of the population in province a in the early stage, but in the later stage, due to the rapid economic growth of the country, a large number of population migration in province a and even the northeast region, which makes the population scale effect restrain EC in the later stage.

Industrial structure effect: it can be seen from the second chapter that province a began to optimize and upgrade its industrial structure in 1998, gradually increasing the proportion of high value-added manufacturing and tertiary industry. In general, the industrial structure effect inhibited the growth of EC from 1997 to 2015, inhibiting the growth of 8.479 million tons of standard coal, accounting for -6.8% of the change in EC. It can be seen from the table that the contribution rate of industrial structure effect to promoting the growth of EC fluctuates. However, since 2012, the industrialization process has gradually transitioned to the late stage of industrialization, and the industrial structure is more reasonable. The effect of industrial structure continues to inhibit the growth of EC, indicating that the adjustment of industrial structure in the province plays a positive role in reducing EC.

Effect of EC structure: including the impact of EC structure on changes in EC of production departments and residents. It can be seen from the table that the change of EC structure only increases EC by 60000 tons of standard coal, and its contribution rate to the change of EC is only 0.048%, which means that the EC structure has little effect on the growth of EC. Although the change of EC structure has no effect on the growth of EC, the gradual transformation of EC structure to clean energy has reduced fossil EC, thereby reducing environmental pollution.

Urbanization effect: the increase of urbanization rate must be the result of the increase of urban population, and the increase of urban population will inevitably lead to the increase of EC, because the construction of public service facilities in the process of urbanization will increase the demand for energy. This is also in line with the data in the table. The urbanization effect has been a driving force for the growth of EC.

Per capita living EC effect: with the rapid economic development and the continuous improvement of people's living standards, it will inevitably lead to the growth of residents' living EC. Overall, the effect of per capita living EC ranks second among the positive factors, and its contribution rate is only less than the output scale effect, which is 7.7%. However, with the further development of the economy and the gradual entry into a well-off society in an all-round way, this will further increase residents' domestic EC, thereby promoting the growth of EC in the province. Therefore, changing residents' consumption concept and cultivating and enhancing residents' awareness of energy conservation play a very important role in energy conservation.

## 5. Conclusion

Based on LMDI DM, this paper analyzes the changes and causes of EC elasticity coefficient, and has achieved good results; Due to the limitations of time, funds, materials and other aspects, the research of this paper is not deep enough. The main shortcomings of this paper first lie in the uncertainty of some data. Because it is difficult to obtain part of the data, some data assumptions are made in the drawing of energy distribution map and LMDI decomposition analysis; Quantitative analysis of various factors affecting the change of EC elasticity coefficient, especially the impact of energy price change on EC elasticity; The elasticity coefficient of EC of developing countries and developed countries is compared and analyzed, and this is further evaluated; Analyze the differences of EC intensity among provinces and cities in China, find ways to reduce EC, and provide countermeasures for the provincial and municipal governments to complete the national EC decline indicators; The impact of information technology on the elasticity coefficient and intensity of EC needs to be further studied.

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## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

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