Research and empirical analysis on structural decomposition model of energy saving contribution sources for provinces in China

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Abstract. With the continuous improvement of China's economic scale and increasing energy demand, various regions have become increasingly dependent on energy, and energy conservation has become an important measure to ensure energy security and protect the environment. In this context, in order to ensure the targeted implementation of energy-saving and emission reduction measures in various regions and promote the gradual transition of China's economy to low-carbon green, this paper analyzes the current energy consumption status of each province and decomposes its energy conservation contribution source structure. And an empirical analysis was carried out to effectively promote the implementation of energy conservation in China.

1. Introduction
With the tightening of energy and environmental constraints of China's economic growth, the dependence of various regions on energy is increasingly aggravated [1]. In order to alleviate the energy crisis and the environmental problems caused by it, energy conservation has attracted the government's great attention. Due to the different energy consumption structure in different regions, the corresponding energy conservation policies should be formulated according to the specific situation. Therefore, a correct understanding of the current energy consumption situation and consumption structure in different regions of China, as well as identifying and optimizing the key factors affecting energy conservation, is an effective means to promote the common development of energy, economy and environment. A series of problems brought about by the continuous development and utilization of energy [2] have aroused the high attention of many scholars. Some scholars have analyzed China's energy consumption process, and proposed energy structure adjustment ideas under the constraints of economic and environmental objectives from two aspects of energy structure and environmental quality [3]. In view of energy saving and emission reduction, some scholars analyzed the irrationality of primary energy consumption structure from the perspective of the contribution rate of primary energy to economic growth, and put forward effective measures to reduce energy consumption and improve energy utilization rate [4]. However, most of the current studies are based on the national energy consumption situation for energy
conservation analysis, and there are few studies on the analysis of energy conservation factors in different provinces.

Therefore, this paper will combine the energy consumption of China's provinces during “the 11th Five-Year Plan” and “the 12th Five-Year Plan”, and get the key factors affecting the contribution of each province through factor decomposition and empirical analysis, so as to provide guidance for the implementation of China's energy conservation measures.

2. Current status of energy consumption by province

Affected by economic development and population growth, China's industrialization and urbanization process has been gradually accelerated in recent years. In addition, China's energy consumption is increasing and the energy consumption situation of each province shows different characteristics [5].

Figure 1. Changes in total energy consumption in China from 2005 to 2015

Figure 1 shows the change trend of China's total energy consumption. As can be seen from the figure, China's total energy consumption showed a steady trend of rise from 2005 to 2012, until 2013 when China's total energy consumption declined. After 2013, China's total energy consumption continued to increase, but the growth rate began to slow down, far less than that of previous years. At the regional level, the total consumption of provinces and cities shows certain differences in the trend of increasing year by year, as shown in figure 2.

Figure 2. Changes in total energy consumption by province in China from 2005 to 2015
In recent years, Shandong, Hebei, Guangdong, Jiangsu and other provinces have been consuming a large amount of energy. By 2015, the total energy consumption reached more than 250 million tons of standard coal. Shandong's total energy consumption has been far higher than that of other provinces. On the one hand, Shandong is a province with large population and industry and huge energy consumption demand. On the other hand, Shandong is in the accelerated stage of industrialization and urbanization, and its energy demand has increased sharply. Provinces with low overall energy consumption, including provinces such as Hainan, Qinghai and Ningxia, have consistently consumed less than 50 million tons of standard coal. Hainan's total energy consumption is the smallest. This is because Hainan's current main industrial pillars are tourism and real estate, and the population distribution is less for other provinces and cities, resulting in limited energy consumption demand. The total energy consumption of other provinces is mostly between 50 million and 20 million tons of standard coal, and the large areas are mostly the economically developed eastern regions or the energy-rich western regions.

3. A model of the influence of key factors on energy saving contribution

In order to promote the realization of China's energy consumption goals, it is necessary to clarify the key factors affecting energy consumption [6]. In this section, a decomposition model is established to calculate the contribution of key factors to energy conservation in each province, so as to provide a basis for reasonable control of energy consumption in the future.

Energy intensity is an important indicator of energy utilization efficiency. Another perspective of energy consumption research is factor decomposition of energy intensity change [7]. Based on various industrial factors, this method decomposes the change of energy intensity into industrial structure effect and industrial intensity effect from the perspective of output volume and energy intensity of each sector and the proportion of each sector in total industrial output. The structural effects and intensity effects reflect the effects of changes in the output structure of various sectors of the industry and changes in energy use efficiency on macro-energy intensity changes. This paper uses the improved Fisher Index algorithm based on the Laspeyres algorithm to decompose energy intensity changes, which studies the change of energy intensity from the ratio of energy intensity at the end of the period to energy intensity at the beginning of the period.

\[
D_{tot} = I_T / I_0 = D_{st}D_{int} \tag{1}
\]

\[
D_{st} = \sum S_{i,T}I_{i,0} / \sum S_{i,0}I_{i,0} \tag{2}
\]

\[
D_{int} = \sum S_{i,T}I_{i,0} / \sum S_{i,0}I_{i,0} \tag{3}
\]

\[
D_{rad} = D_{tot} / (D_{st}D_{int}) \tag{4}
\]

Where \( I \) is the total energy intensity. \( D_{tot} \) is the energy intensity of the \( T \)-phase relative to the energy intensity of the base period. \( D_{st} \) indicates changes due to the effects of industrial structure. \( D_{int} \) indicates the change due to the industrial strength effect. \( D_{rad} \) is the residual term item. \( I_{i,T} \) and \( I_{i,0} \) are the energy intensity of the \( i \)-th industry in the \( T \) and base periods respectively. \( S_{i,T} \) and \( S_{i,0} \) respectively represent the proportion of the output of the \( i \)-th industry in the \( T \) period and the base period to the total economic output.

Laspeyres multiplication decomposition has remaining items. The algorithm below is Fisher Index algorithm, which is an improvement of Laspeyres algorithm, and its structure effect and intensity effect are respectively as follows.
4. Empirical Analysis on Key Factors of Energy Conservation Contribution Sources in Different Provinces during the Eleventh Five-Year Plan and the Twelfth Five-Year Plan Period

30 provinces and cities in China were selected as research objects. Firstly, factor decomposition at the national level was carried out, and the results were shown in figure 3.

![Figure 3. Decomposition of industrial factors of China's energy intensity from 2005 to 2015](image)

As is shown in the figure 3, China's energy intensity has been declining continuously in the past decade. The decline of energy intensity is mainly due to the decline of energy intensity of industrial sectors, and the effect of industrial structure plays a small role in the decline of energy intensity, but the energy saving effect of industrial structure gradually increases from 2012. In other words, with the optimization and upgrading of China's industrial structure, the contribution of the structural effect to reducing the overall energy intensity will be more and more obvious.

From the regional level, the structural effect and intensity effect of different provinces are also different. Table 1 shows the factor analysis results of changes in energy intensity of each province from 2005 to 2015. In general, energy saving effect is dominated by industrial intensity effect, and the effect of industrial structure effect varies greatly in different provinces. Therefore, the energy conservation effect change models of 30 provincial-level administrative regions in China are roughly divided into two categories, as shown in table 2.

The change of industrial structure in the first category of provinces promotes the decline of energy intensity, makes a positive contribution to energy conservation, and leads to the ultimate energy saving effect in the same direction as the change of industrial intensity. Among them, the industrial structure effect of Shanxi, Heilongjiang, Shanghai, Jiangsu and other provinces plays a bigger role. The reason is that the proportion of primary industry and secondary industry decreases while the proportion of tertiary industry increases. As a province with a large output of energy, Shanxi has a relatively simple industrial structure in the past, so it has been making efforts on the road of transformation and development. In recent ten years, The change of industrial structure in Heilongjiang brings good energy saving effect, which is the highest among all regions. In the future, it may be necessary to deepen the industrialization process and optimize industrial technology. As economically developed areas along the eastern coast, Shanghai, Jiangsu and other provinces are constantly upgrading their industrial structure while maintaining the rapid economic growth of the industrial sector every year, making a great contribution to energy conservation. In general, part of the region with a large contribution to industrial structure
energy conservation is a large-scale resource-based province dedicated to economic transformation, and the other is a developed eastern economic zone with long-term industrial structure upgrading.

Table 1. Decomposition of industrial factors in the province's energy intensity change from 2005 to 2015

| Province  | Industrial structure effect | Industrial intensity effect | Total effect |
|-----------|-----------------------------|-----------------------------|--------------|
| Beijing   | -10.13%                     | -58.10%                     | -62.34%      |
| Tianjin   | -9.57%                      | -47.19%                     | -52.25%      |
| Hebei     | -6.25%                      | -46.90%                     | -50.22%      |
| Shanxi    | -20.22%                     | -37.03%                     | -49.76%      |
| Inner Mongolia | 7.25%                      | -60.46%                     | -57.60%      |
| Liaoning  | -2.89%                      | -54.11%                     | -57.00%      |
| Jilin     | 9.22%                       | -64.43%                     | -51.15%      |
| Heilongjiang | -28.28%                   | -23.23%                     | -44.94%      |
| Shanghai  | -14.93%                     | -39.72%                     | -48.72%      |
| Jiangsu   | -14.44%                     | -45.40%                     | -53.28%      |
| Zhejiang  | -8.78%                      | -44.10%                     | -52.88%      |
| Anhui     | 14.10%                      | -59.61%                     | -45.51%      |
| Fujian    | 3.40%                       | -51.61%                     | -48.97%      |
| Jiangxi   | 5.17%                       | -54.58%                     | -52.23%      |
| Shandong  | -12.00%                     | -47.97%                     | -54.22%      |
| Henan     | -4.12%                      | -52.75%                     | -54.07%      |
| Hubei     | -9.75%                      | -59.79%                     | -63.71%      |
| Hunan     | 6.77%                       | -66.12%                     | -63.82%      |
| Guangdong | -5.71%                      | -44.73%                     | -47.89%      |
| Guangxi   | 15.36%                      | -58.79%                     | -52.47%      |
| Hainan    | -0.66%                      | -41.11%                     | -41.50%      |
| Chongqing | 0.31%                       | -60.25%                     | -56.13%      |
| Sichuan   | 6.02%                       | -61.05%                     | -58.71%      |
| Guizhou   | -0.25%                      | -66.24%                     | -66.33%      |
| Yunnan    | -1.47%                      | -55.95%                     | -56.60%      |
| Shaanxi   | 1.35%                       | -55.08%                     | -54.47%      |
| Gansu     | -11.21%                     | -44.76%                     | -50.95%      |
| Qinghai   | 2.69%                       | -45.81%                     | -44.36%      |
| Ningxia   | 3.04%                       | -56.48%                     | -55.16%      |
| Xinjiang  | -9.72%                      | -12.07%                     | -20.61%      |

Table 2. Classification of energy saving contributions of various industries in 2005-2015

| Type   | Industrial structure effect | Industrial intensity effect | Total energy saving effect | Province                                      |
|--------|-----------------------------|-----------------------------|---------------------------|-----------------------------------------------|
| the    | negative                    | negative                    | negative                  | Beijing, Tianjin, Hebei, Shanxi, Liaoning,    |
| First  |                             |                             |                           | Heilongjiang, Shanghai, Jiangsu, Zhejiang,    |
|        |                             |                             |                           | Shandong, Henan, Hubei, Guangdong, Hainan,    |
|        |                             |                             |                           | Guizhou, Yunnan, Gansu, Xinjiang             |
| the    | positive                    | negative                    | negative                  | Inner Mongolia, Jilin, Anhui, Fujian, Jiangxi,|
| Second |                             |                             |                           | Hunan, Guangxi, Chongqing, Sichuan, Shaanxi, |
|        |                             |                             |                           | Qinghai, Ningxia                             |

The changes in industrial structure in the second type of provinces have all inhibited the decline in energy intensity and contributed negatively to energy conservation, but still led to the final energy-
saving effect under the adverse effects of industrial intensity changes. It can be seen that most of the provinces with negative industrial structure effect come from the western regions where energy is produced. Among them, Guangxi, Anhui and Jilin have the worst industrial structure effect. Compared with the national average, Guangxi’s industrial structure shows that the proportion of the primary industry is relatively high, and the proportion of the tertiary industry is low. It can be seen that the industrial structure of Guangxi Province is poor, and it is necessary to make greater efforts to adjust. Up to 2015, Anhui province still focuses on the secondary industry. However, as the development of Anhui province's industrial structure is largely subject to the tendency of government policies, it is certain to achieve the optimization and upgrading of industrial structure under the trend of accelerating urbanization construction in the future. As one of the three northeastern provinces, Jilin is also an old industrial base and a big grain-producing province. However, in recent years, Jilin Province has implemented various national policies and measures for energy conservation and consumption reduction. At the same time, it has actively innovated energy technologies, and its energy conservation contribution in the industrial sector has become more prominent. Therefore, the main development direction of energy saving and consumption reduction in Jilin Province in the future is the optimization and upgrading of industrial structure. On the one hand, it can accelerate the development of the tertiary industry, especially the productive service industry. On the other hand, it can accelerate industrial transformation and upgrading, and enhance industrial competitiveness.

5. Conclusion

Based on the current situation of energy consumption in various provinces of China, this paper establishes a model of the key factors of energy conservation contribution. Then this paper selects 30 provinces and cities in China during the “Eleventh Five-Year Plan” and “Twelfth Five-Year Plan” to conduct empirical analysis. As a result, the energy conservation effect change models of 30 provinces are divided into two categories. The first category is that the industrial structure changes negatively and the industrial structure promotes energy conservation effects. The second category is that the industrial structure changes positively, and the industrial structure inhibits energy conservation effects.

Acknowledgments

This work was financially supported by Science and Technology Project of State Grid Corporation fund (Research on Structural Decomposition and Potential Evaluation Model of Energy Saving in the Whole Society for China) (5202011600UA).

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