Analysis on the degree of the industrial structure’s impact on the energy consumption--Based on empirical study of Guangdong Province

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Abstract

This paper uses two methods LMDI and Laspeyres to analysis the influences the industrial structure has on energy consumption ,including how much the three industries have contribution to energy intensity .The results we conclude are :1) Economy has a strong stimulating effect on energy consumption;2)The effect of improving energy efficiency by using science and technology is significant in Guangdong province, especially in the secondary industry; 3)The secondary industry plays a positive role in reducing energy intensity , and the advantages of the tertiary industry isn’t displayed .

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Key Words: Industrial structure, Energy consumption, Energy intensity, Guangdong province

1. Introduction

Achieving balanced development between energy and economy is an important topic that human concern currently. In recent years, Guangdong province has done a lot of work in upgrading industrial structure and energy efficiency. It will helpful for evaluating the industry and energy saving measures objectively to analyze the impact effects the industrial structure and energy efficiency had on energy consumption and analyze the contributions that the three industries had on energy intensity.

This paper attempts to use the LMDI and the Laspeyres methods to analysis the impact degree that the industry structure has on energy consumption. And then we study the behind reasons of the continuous
reductions of energy intensity in Guangdong province. These studies will have extremely important theoretical and practical significance on achieving the “Eleventh five-year” energy saving goals and the “double shift” strategy in Guangdong province. The paper will provide some guidance for industrial structure upgrading.

2 Impact mechanisms

2.1 Conception of energy intensity

Energy intensity we can also say energy consumption of per unit GDP\(^a\). It is the amount of energy consumption per unit output of a region, sector or industry in a certain periods usually a year. It reflects the energy efficiency and the degree of economy's dependence on energy. It is determined by the amount of total economic output and energy consumption. It’s also the results of technological progress of energy, management and institutional innovations essentially.

2.2 Impact mechanisms

From the general evolution of industrial structure and energy consumption, there are some certain correlations between industrial structure and energy consumption. In the first phase of industrial structure, with the industrial structure dominated by agriculture developing to industrial structure dominated by light industry, the energy intensity increases slowly and the constrain that energy has on economic growth is not yet clear. When the industrial structure is developing from light industry to heavy industry, energy demand and energy intensity is growing rapidly, the rate of energy growth begins to exceed the rate of economic growth, energy consumption elasticity\(^b\) is greater than 1 and energy is becoming an important factor to restrict economic development. When the industrial development comes into the “technology intensive” phase, the science and technology is becoming major product factor, and energy efficiency increases substantially, energy intensity begins to decrease and becomes stable finally. We can see that if only optimizing the industrial structure continuously and making economic growth more intensive, energy will not become a bottleneck of economic development, according the general laws of economic development and the evolution law of industrial structure.

2.3 Analysis of influence way

The adjustment of industrial structure has influence on the energy intensity through two channels, the direct and the indirect channel. The direct channel means to reduce energy intensity by reducing the proportion of high energy consumption industries or increasing the proportion of low-energy industry output, which means reducing the direct energy demand through upgrading the industrial structure. The indirect channel means reducing the energy demand indirectly. It includes two aspects: First, we can reduce energy consumption through industry associations; reduction of the proportion of a high energy consumption industry may lead to the reduction of its upstream and downstream industries’ energy consumption. Second, we can reduce energy intensity further by reducing the demand of high energy consumption products.

\(^{a}\) In this paper we calculate the consumption intensity by energy consumption (million tons of standard coal)/GDP or industrial added value in comparable prices.

\(^{b}\) Energy elasticity is an indicator that reflects the proportional relationship between energy consumption growth rate and economic growth rate. It usually means the ratio between the two average annual growth rate.
3 Analysis on the degree of influence

3.1 Selection of the methods

There are many methods for analyzing the factors of energy consumption currently, such as Laspeyres, Divisia, Passche, Fisher, Marshall-Edgeworth, and input-output, and other methods, of which the first two methods are widely used in research. According to the basic methods, Sun proposed “the Laspeyres’ method of complete decomposition”, Ang introduced the details of the logarithmic mean Divisia decomposition method which effectively solve the remaining issues in decomposition; Liu and others proposed adaptive weighting decomposition of Divisia, thus it avoided subjectivity and arbitrariness of the parameter estimation.

Scholars from domestic and foreign have made a lot of study on the impact factors of energy consumption, and most of which is to study the industrial sector by adopting one method, little from the overall and macro perspective. In this paper, we use two ways to analyze energy consumption from the overall and the partial perspective. Firstly, we choose the LMDI method which proposed by Ang (2004) to analyze the impact the industrial structure has on energy consumption from the overall perspective. Subsequently, we analyze the contribution degree of the three industries have to the energy intensity by using the decomposition method.

3.2 Data selection

Data of this part is mainly from the statistical yearbook of Guangdong province, all the data analysis is based on the 1995-2008. For better comparing and analyzing, this part use comparable data to analyze (we take the year of 1995 as the basic year). Meanwhile, we used the three industrial added value as the total GDP.

3.3 Description and derivation of indicators

3.3.1 Description of LMDI and derivation of indicators

\[ E = \sum E_i = \sum Y_i \cdot P_i \times \frac{y_i}{Y_i} = \frac{E_i}{Y_i} \]

\[ \Delta E = E_i - E_{i0} = \Delta E_{jgc} + \Delta E_{cij} + \Delta E_{ney} + \varepsilon \]

\[ \Delta E_{jgc} = \sum w_i \cdot \ln(Y_i / Y_{i0}) \]

\[ \Delta E_{cij} = \sum w_i \cdot \ln(y_i / y_{i0}) \]

\[ \Delta E_{ney} = \sum w_i \cdot \ln(P_i / P_{i0}) \]

These above are the decomposition model expressions. In which \( \Delta E \) represents the total effect, \( \Delta E_{jgc} \), \( \Delta E_{cij} \), \( \Delta E_{ney} \) respectively represent economic growth effect, industrial structure effect and the effect of energy efficiency, and \( \varepsilon \) represents the effect that can’t be explained by the above three parts. \( \Delta E_{jgc} \) means that the changes of energy consumption caused by economic growth when industrial
structure and energy efficiency kept in the same circumstances; $\Delta E_{\text{ost}}$ represents the variation of energy consumption caused by industrial structure when we suppose economic growth and energy efficiency kept in the same circumstances; $\Delta E_{\text{nyd}}$ represents the effect of energy efficiency when the output and industrial structure kept stable. More details of the target indexes are lined in Table 1.

Table 1: index’s selection and details

<table>
<thead>
<tr>
<th>Index</th>
<th>details</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$</td>
<td>$E = \sum E_i$, $E$ represents the total amount of energy consumption</td>
<td>10000 tons</td>
</tr>
<tr>
<td></td>
<td>$E_i$ represents the energy consumption of the $i$ industry</td>
<td>standard coal</td>
</tr>
<tr>
<td>$Y$</td>
<td>$Y = \sum Y_i$, $Y$ represents value of the $i$ industry sector</td>
<td>1000 billion</td>
</tr>
<tr>
<td></td>
<td>$y_i = Y_i / Y$ , $y_i$ represents proportion of the $i$ industry in overall industries</td>
<td>%</td>
</tr>
<tr>
<td>$P$</td>
<td>$P = E / Y$, $P$ represents overall energy intensity</td>
<td>10000 tons</td>
</tr>
<tr>
<td></td>
<td>$P_i = E_i / Y_i$, $P_i$ represents energy intensity of every industry</td>
<td>standard coal per</td>
</tr>
<tr>
<td></td>
<td>$10000yuan$</td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Total factor analysis of indicators derived

In the LMDI, the energy consumption is decomposed in four parts: industrial structure, economic growth, energy efficiency and the part can’t be explained by above three parts. To make more specific research, we also need to use the complete decomposition to compare the structure and efficiency contributions of energy intensity in three industrial sectors further.

The following is the derivation of the statistical indicators:

$$P = \frac{\sum E_i}{\sum Y_i} = \frac{\sum P_i * y_i}{\sum y_i} = \sum P_i * y_i$$

$$\Delta P = P - P_0 = \sum \left( P_i - P_0 \right) * y_i - \sum P_0 * y_i$$

$$\Delta P = \sum \left( P_i - P_0 \right) * y_i$$

$\frac{1}{2}(P_i + P_0) * (y_i - y_0)$ represents the variation in energy intensity caused by the share change of $i$-industry in total output, $\sum \frac{1}{2}(P_i + P_0) * (y_i - y_0)$ represents the variation of energy intensity caused by the changes in overall economic structure. So the share of the efficiency is $\frac{\sum \frac{1}{2}(P_i - P_0) * (y_i + y_0)}{\sum P_0 * y_i - \sum P_i * y_i}$

$^5$ The complete decomposition method is proposed by Sun. It can be also called Laspeyres method. Its basic idea is that a variable target was divided into several elements, which can identify the degree of influences of the various elements and then determine the relative large factors.
The contribution rate of structure is 
\[ \sum (p_i - p_o)(y_i - y_o) \] 
for \( t=1, 2, 3 \) (3); The contribution rate of efficiency is 
\[ \sum (p_i - p_o)(y_i + y_o) \] 
for \( t=1, 2, 3 \) (4); The contribution rate of structure is 
\[ \sum (p_i + p_o)(y_i - y_o) \] 
for \( t=1, 2, 3 \) (5).

3.4 Results of analysis

3.4.1 Conclusions based on LMDI method

LMDI analysis showed that the economic growth and industrial structure had a positive effect on energy consumption, while energy efficiency had a large negative effect on energy consumption (see figure 1). In 2008, the expansion of economic output made energy consumption increased by 19.49 million tons of standard coal, the factor of industrial structure made the energy consumption increased 955200 tons standard coal and the energy efficiency made the energy consumption decreased by 10.17 million tons standard coal, and the other factors that can’t be explained by the model had a positive effect on the energy consumption.

The industrial structure had a positive effect on energy consumption in 1995-2008 periods in Guangdong province, especially in 2003, the positive effect reached 2.15 million tons standard coal and in 2008 the positive effect decreased significantly. With the adjustment of the industrial structure, the heavy industry has began to develop since 2000, and in 2002, the proportion of heavy industry was greater than the light industry’s for the first time, which the ratio of output value of the two industries was 49.8:50.2. This is the reason for the highest positive effect of the industrial structure in 2003.

Energy efficiency showed an obvious negative effect on energy consumption in Guangdong. In 2008, the negative effect of energy efficiency reached 10.17 million tons standard coal, while the total effect was 11.60 million tons standard coal, the contribution rate of energy efficiency was 87.9%.
Fig1: the decomposition results of LMDI method in 1995-2008

Source: 《Guangdong Statistical Year-book》 1995-2009. The positive number indicates that the effect causes the increasing of energy consumption, otherwise it causes the decreasing.

### 3.4.2 Conclusions based on total factor analysis

From the structural contribution rate of the three industries (see table 2), we can conclude that the structural contribution of the secondary industry was the most significant. The structural contribution rates were all positive in 1995-2008, moreover the contribution rate reached more than 100% in every year except 1995, the highest rate was 143.08%. The structural contribution rate of the tertiary industry performed less stable. A negative contribution showed since 2004, which indicated that the proportion changes of the tertiary industry and the changes of the overall energy intensity were in the opposite direction. The structural contribution rate of the primary industry was bigger than the tertiary industry’s. The direction of the energy intensity caused by the primary industry and the direction of the overall energy intensity were opposite, which showed that although the structure of the primary industry was optimized, there are still efforts need to be enhanced.

From the efficient contribution rate of the three industries (see table 2), we can conclude that the efficient contribution of the secondary industry was also the most significant. In 2008, the contribution rate reached 93.74%. In 2005, the rate reached above 100%, which indicated that the direction of the secondary industry changing dominated the direction of the changes of the overall energy intensity. Besides, the energy intensity of tertiary industry also played a certain role on the efficient contribution rate.

<table>
<thead>
<tr>
<th>YEARS</th>
<th>Primary industry</th>
<th>Secondary industry</th>
<th>Tertiary industry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Structure share</td>
<td>Efficiency share</td>
<td>Structure share</td>
</tr>
<tr>
<td>1996</td>
<td>-0.4237</td>
<td>0.0025</td>
<td>1.3360</td>
</tr>
<tr>
<td>1997</td>
<td>-0.3443</td>
<td>0.5953</td>
<td>1.3311</td>
</tr>
<tr>
<td>1998</td>
<td>-0.3580</td>
<td>0.0358</td>
<td>1.3589</td>
</tr>
<tr>
<td>1999</td>
<td>-0.3842</td>
<td>0.0560</td>
<td>1.3171</td>
</tr>
<tr>
<td>2000</td>
<td>-0.4864</td>
<td>0.0317</td>
<td>1.3276</td>
</tr>
<tr>
<td>2001</td>
<td>-0.5606</td>
<td>0.0243</td>
<td>1.3239</td>
</tr>
<tr>
<td>2002</td>
<td>-0.5028</td>
<td>0.0364</td>
<td>1.3014</td>
</tr>
<tr>
<td>2003</td>
<td>-0.3396</td>
<td>0.0583</td>
<td>1.3103</td>
</tr>
<tr>
<td>2004</td>
<td>-0.3266</td>
<td>0.0444</td>
<td>1.3662</td>
</tr>
<tr>
<td>2005</td>
<td>-0.3850</td>
<td>0.0132</td>
<td>1.4273</td>
</tr>
<tr>
<td>2006</td>
<td>-0.3553</td>
<td>0.0224</td>
<td>1.4159</td>
</tr>
<tr>
<td>2007</td>
<td>-0.3409</td>
<td>0.0250</td>
<td>1.4189</td>
</tr>
<tr>
<td>2008</td>
<td>-0.3392</td>
<td>0.0237</td>
<td>1.4308</td>
</tr>
</tbody>
</table>

Source: Guangdong Statistical Yearbook. Note: Positive sigh represents that energy consumption of industry and total energy consumption have the same changing direction; And the negative sigh represents that industry structure and the efficiency hinder the energy intensity to decline.
4 Conclusions

4.1 Economic growth plays a positive role in energy consumption recently in Guangdong province

Energy is necessary production factors for civilization. And the development of economy is based on the energy. Energy consumption promotes economic growth, meanwhile economic growth lead to large-scale development and utilization of energy. Analysis of LMDI shows that economy has a strong positive stimulus on energy consumption.

And form the changes of energy consumption in Guangdong province we can see (see Figure 2) that with the increasing of economy total energy consumption in Guangdong province is on the rise. Because of other factors such as energy structure improving, energy efficiency increasing and industrial structure adjusting and so on, the growth rate of energy consumption decreases year by year. The growth of energy consumption in 2008 was lower than the growth in 1991, decreased about 10.17 percentage points. And in 2008 the growth rate of energy consumption was the first time lower than the growth rate in China.

![Total national energy consumption and Total energy consumption in Guangdong](image)

Fig 2: The situation of energy consumption in Guangdong province and in China

4.2 Energy efficiency has a significant role on energy saving

Energy efficiency not only reflects the degree of the energy saving technologies but also reflect the degree of industrial structure to some extent. So the effect of energy saving technology has a far-reaching influence on realizing the energy goals in Guangdong province. Analysis of the three industry contribution to energy intensity shows that the decline of energy efficiency in the secondary industry was the main reason for the declining of energy intensity in Guangdong province.

From the trend of energy intensity of the three industries, we can conclude that the secondary industry’s intensity declined obviously. The energy intensity of the secondary industry was 1.288tons standard coal/10000yuan in 2008, this was less than the 4.507tons standard coal/10000yuan in 1990. We can attribute the decrease mainly to two aspects. On the one hand, the proportion of the secondary industry decreased; on the other hand, the industrial sector with high energy consumption improved the energy efficiency of their production processes and products. The energy intensity of tertiary industry is higher than the primary industry’s, which is concerned with the inner restructuring of the tertiary industry sectors (see figure 3). Take the transportation for example the transportation has developed rapidly in recent years in Guangdong province, which increased the proportion of the energy consumption of the tertiary industry. So in the future Guangdong should optimize structure in the tertiary industry and make a good progress in improving energy efficiency of the tertiary industry.
4.3 Adjustment of industrial structure need to be optimized further in Guangdong province

Overall, the potential contribution which industry structure having to energy intensity needs to be further tapped. Elements analysis showed that the secondary industry played a positive role on the declining of energy intensity, the advantage of the tertiary industry has not displayed; the structural contribution rate of the primary industry was greater than the tertiary industry’s. Meanwhile, we need do lots work to increase the primary industry’s added value.

In recent years, with the economy in Guangdong booming and expanding, the secondary and tertiary industries grew rapidly. The pattern of secondary and tertiary industries has kept pace with each other. In 2008, the three industrial structure was 5.5:51.6:42.9, while in 1978, it was 29.8:46.6:23.6. Although the industrial structure in Guangdong has changed better and better, it is still facing the pressure of optimizing and continuous adjusting. With the major strategic decision implementing such as “double shift” and “establishing a modern industrial system”, the three industries in Guangdong will accelerate their upgrading paces.

In 2008, the energy consumption of secondary industry accounted for 75.84% in three industries (see figure 4). With the output of the secondary and tertiary industries increasing steadily and the growth rate of energy consumption of the two industries changing uncertainly, we can conclude that industrial structure upgrading and energy saving also contain a daunting task although they had achieved certain results.
Fig 4: Status of the three industries’ energy consumption in Guangdong province

5 Recommendations

Fluctuation of the industrial structure is the main factor leading to the fluctuation of energy consumption. Currently, industrial structure has a positive role on energy and the potential ability of industrial restructuring for saving energy is still great. Therefore, when the government of Guangdong province makes economic development plans and energy production plans, they should take full account of the industrial structure’s impact on energy. We should make the development of industrial structure and energy consumption structure adapt to each other. There are several measures to achieve our goals, such as adjusting industrial structure constantly, paying more attention to service industries, particularly modern service industries, increasing financial support on the modern manufacturing industry, reducing energy intensity in heavy industrial sectors through clean technology.

References