Research on the Relation Model between Energy Efficiency and Industrial Structure Transformation Based on Mathematical Statistics

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Abstract

Through decades of unremitting efforts, the overall development of China's economy has been of good shape, showing continuous growth trend. So-far the development of the total output of the economy has been ranked among the top three in the world, and the quantity of energy consumption has been on the increase along with the growing economy. However, at the same time, it is precisely because of energy, it leads to the irrational structure of China's industry. The overall efficiency of energy utilization is relatively low; the existing problems seriously affected the sustainable development of China's current economy. The various types of documents from Chinese government also mention the optimization of the industrial structure, natural environment protection and sustainable economic development, etc. It also reflects the urgency of optimizing China’s industrial structures and improving the efficiency of energy utilization. Therefore, in this context, combined with the current domestic hot issues, it hopes to carry out in-depth analysis of energy efficiency, industrial structures and the relationship between the two, in order to further help the domestic industries to adjust themselves, effectively improve the energy efficiency, and promote the sustainable development of China's economy.

Keywords, Mathematical Statistics Method, Energy Efficiency, Industrial Structure, Relation Model.

1. RESEARCH BACKGROUND

1.1 Literature Review

China's current energy efficiency is still at a low stage of development, and the overall efficiency is low. There is a big gap when compared with the western developed countries. It even has not yet reached the requirements of the world's lowest level. China's total energy consumption in 2015 was 38.4 tons, accounting for 25% of the world's total energy consumption. The energy intensity was 3.5 times of that of the world's average level, 3.7 times of that of the United States, and 8 times of that of Japan. At the same time, when compared with the developing countries, such as Brazil, India of BRIC countries, China’s energy intensity are more than that of these countries (Xu, 2015).

It can be fully seen that the overall situation of energy consumption in China can be summed up as that the total energy consumption is large while the energy efficiency is low. Therefore, to improve such situation, it is imperative to promote energy efficiency and reduce the total energy consumption. Many researchers agree that there are many reasons impacting energy efficiency, including the energy price, the national economic development situation, and the industrial structure directly. Among them, the changes of industrial structure are one of the main factors influencing the energy efficiency, and the main features of the industrial structure directly determine the efficiency of energy utilization (Xu, 2016). In terms of comparison of energy demand, usually the second industry has more demand. According to a large number of research results, it shows that the energy consumption of the secondary industry are mainly from industrial manufacturing, steel production, chemical enterprises, construction industry and non-ferrous metals industry and other high energy consumption industries. The energy consumption of these related industries accounts for a larger proportion of the overall industrial consumption. Therefore, it should explore the impact of energy efficiency on industrial structure transformation, analyze the meaning and characteristics of the two, sort out the relationship between each other, clarify the impact of industrial structure adjustment on energy efficiency, in order to optimize the industry, to improve energy efficiency, which has great practical significance for the further development of China's economy (Xu, 2013).

1.2 Research Purpose

First of all, the research is conducive to having a more profound understanding of the transformation of the industrial structure. In recent years, the continuous adjustment of industrial structure is related keywords
mentioned many times of the government policy. But the public does not have a comprehensive or a clear understanding of it. Through the discussions of industrial structure and characteristics, it can make more people master the specific knowledge which has a crucial role in helping promote the optimization of China's industrial structure (Huo, 2010). Secondly, it is possible to further clarify the main direction of future industrial restructuring, through the analysis from all angles, the detailed adjustment program can be concluded. Finally, according to the impact of industrial structure on energy efficiency, it can clarify the relationships between each other, and truly improve the energy efficiency.

2. A COMPREHENSIVE OVERVIEW OF ENERGY EFFICIENCY AND INDUSTRIAL STRUCTURE

2.1 Concept of Industrial Structure

Under normal circumstances, the industry is a middle economic meaning between a macroeconomic one and a microeconomic one. When the social and economic development reach a certain extent, the goods of the fine classified production in the various types of activities of social production will be produced with the distribution of the society and will be improved along with the development of society. In details, it mainly refers to the economic groups formed by the enterpriseor composed by the legal representative enterprise which are with the same characteristics (Tang, 2009). In the economic field, the definition of industrial structure was not clearly identified until 1940s, and was identified as the proportional relations between the composition of the industry and the various industries. The relations between the departments of the industry and their different proportional relations have different roles to play in the economic development. The evaluation of the industrial structure put more emphasis on the quality. Among them, the so-called "quality" can dynamically reflect the inter-industry technical and economic ties and the changing trend of their contacts, exposing the law concerning the changing dominant industrial sectors and its corresponding "structural" efficiency of the process of economic development, which is the so-called narrow sense of the industrial structure theory (Li, 2014). The "quantity" can be a static study of the quantitative relations between the industries and the ways of contacts of a certain period of time, that is, the ratio of the "investment" to the "output", and thus it forms a theory which has a direct link with the industry. In a broad sense, the theory of industrial structure also contains the industrial structure theory of a narrow sense and a direct contact theory concerning the industries.

2.2 Overview of Industrial Rationalization

Based on the detailed data collected on the industry and employment structure of China from 2010 to 2016, it has chosen the structural numerical deviation method and Theil Index method which are scientific, reasonable and easy to operate of the measurement methods are concerning the rationalization of the industrial structure. The details of calculation table are shown in Table 1.

**Table 1 Industry and Employment Structure in China In 2010-2016 Years**

<table>
<thead>
<tr>
<th>Particular year</th>
<th>industrial structure</th>
<th>employment structure</th>
<th>Structural deviation</th>
<th>Theil index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary industry</td>
<td>secondary industry</td>
<td>tertiary industry</td>
<td>Primary industry</td>
</tr>
<tr>
<td>2010</td>
<td>0.111</td>
<td>0.479</td>
<td>0.409</td>
<td>0.426</td>
</tr>
<tr>
<td>2011</td>
<td>0.108</td>
<td>0.473</td>
<td>0.419</td>
<td>0.408</td>
</tr>
<tr>
<td>2012</td>
<td>0.107</td>
<td>0.474</td>
<td>0.418</td>
<td>0.396</td>
</tr>
<tr>
<td>2013</td>
<td>0.103</td>
<td>0.462</td>
<td>0.434</td>
<td>0.381</td>
</tr>
<tr>
<td>2014</td>
<td>0.101</td>
<td>0.467</td>
<td>0.432</td>
<td>0.367</td>
</tr>
<tr>
<td>2015</td>
<td>0.100</td>
<td>0.466</td>
<td>0.434</td>
<td>0.348</td>
</tr>
<tr>
<td>2016</td>
<td>0.101</td>
<td>0.453</td>
<td>0.446</td>
<td>0.336</td>
</tr>
</tbody>
</table>

It can be seen from Table 1, according to the calculation method of the rationalization of the industrial structure, there is a big difference between China's industrial structure and employment structure. For example, the proportion of the first industry in 2001 was 10.8%, while the proportion of employment in the relevant industry was up to 40.8%. Even in 2016, there was still a serious difference between the industrial structure and the employment structure (Gao, 2015). When compared with the corresponding standard model of industrial structure, it can find that China's industrial structure is not reasonable at present. And then it draws the deviation from the Theil Index, as shown in Figure 1.
It can be seen from Figure 1 that between 2010 and 2016, the structural deviation and the change of Theil Index were almost coincident, and there were no large changes in the whole. But the overall decline can be seen, which means the low degree of reasonableness of the industrial structure. This has a direct impact on the use of energy efficiency (Wang, 2008).

2.3 Concept of Energy Efficiency

Energy efficiency is usually referred to mainly the production capacity on the basis of the given total energy, and the energy efficiency can generally be divided into physical efficiency and economic efficiency. The measurement of physical efficiency is based on three steps from the mining, transport to the utilization, namely the mining efficiency, the efficiency of processing and transformation intransporting, and efficiency of preservation of transport, and then to the final utilization efficiency (Gong, 2015). Therefore, the physical efficiency in energy efficiency includes the multiplication of mining efficiency, intermediate step efficiency and utilization efficiency. And economic efficiency refers to the intensity of energy, that is, the energy used by the unit economy is generally expressed in terms of energy intensity in the economic category, that is, the ratio of total energy consumption to the total domestic production. Energy intensity includes the impacts from the economic development of the country or region, economic organization, energy organization, technical capacity, marketization situation, management level and other factors on the energy efficiency, and to some extent, it also reflects the energy conversion efficiency and energy consumption per product unit. It shows the energy efficiency of country or region from a macro point of view.

2.4 Analysis of the Present Situation of Energy in China

For China’s current energy efficiency as a whole, the common understanding is that in terms of energy efficiency, there is a large degree of gap between that of China and those of the developed countries, which is below the world’s average level. Related survey data show that China’s energy intensity in 2014 was 2.3 times of that of the world’s average level. When compared with those of United States, Britain and Japan, it was more than three times higher than those of these developed countries (Wang, 2013). At the same time, in terms of the levels of efficiency of energy utilization in China, there is a large gap between the various regions of the country. Among them, the coastal areas of the southeast of the country have the highest energy efficiency, the northern coastal areas and the southwest regional energy efficiency are at a moderate level, while the middle reaches of the Yellow River, and the northwest and northeastern areas have the lowest level of energy efficiency.

3. RELATION BETWEEN ENERGY EFFICIENCY AND INDUSTRIAL STRUCTURE

The 2016 data of China’s economic statistics shows that the total production of the China’s third industry accounted for 43.1% of the total domestic production, and the ratio of the countries of Organization for Economic Cooperation and Development (OECD) have averaged more than 75%, for instance, 76.3% in the United States, 74.8% and 50.4% in Brazil and India respectively, which are similar in terms of the overall development to China (Zhu, 2014). The forecast data statistics show that if China’s third industry increases by 1 percentage point higher
than the average proportion, and the proportion of total industrial growth in the secondary industry decreases by one percentage point, then the total energy consumption per ten thousand yuan can reduce about one percentage point. It can fully see from the picture that during the current period, the industrial structures will directly affect China’s energy efficiency. Figure 2 is the proportion of the third industry of different regions of China in 2016.

![Figure 2. Statistics of Third Industries In 2016](image)

The figure above clearly shows that the industrial structure and energy efficiency has a direct relation, and the elements of the industrial structure affect the energy efficiency. First of all, from the analysis of structural factors among the industries, the impact of inter-industry structural change on energy efficiency is mainly caused by the different energy intensities of each industry. If the energy intensity is high, its proportion of GDP in GDP is larger and the increase rate is also faster, the total energy intensity will also increase, leading to lower energy efficiency (Lv, 2014). Generally speaking, the energy intensity of the primary industry is the lowest, and the energy intensity of the secondary industry is the highest, of which the energy intensity is particularly prominent, while the energy intensity of the third industry is between the primary industry and the secondary industry. With the economic development and Gross Domestic Product (GDP) growth, the proportion of industrial structure will continue to evolve. The main proportion will shift from the primary industry to the secondary industry, and the final optimization situation will fall on the third industry. Therefore, from the overall trend of economic development, the structural characteristics of the three industries are as follows. The beginning is a “the first industry is bigger than the secondary industry which is bigger than the third industry” pattern. With the continuous industrialization progress and economic development, it will become a “the secondary industry is bigger than the third industry which is bigger than the first industry” pattern. And ultimately with the optimization adjustment of economic structure, it will become a “the third industry is bigger than the secondary industry which is bigger than the first industry” pattern (Wang, 2013). It can be argued that as the economy continues to evolve, the energy intensity should rise first and decline later.

Secondly, it analyzes the impact on the energy efficiency from the internal structural factors of the industry. Most of the current researches are to enhance the level of science and technology as an effective way to enhance China’s energy efficiency. The assessment basis lacks the consideration of the structural factor due to the promotion of the energy efficiency of a certain industry, which is clearly not scientific. From the point of real situation, the industry’s detailed industrial structure elements have great significance in the energy intensity changes of the industry as a whole. Under certain conditions, they even have serious impacts on their own industries’ energy intensity. Therefore, from the macro level, it is immature draw a general conclusion just from a few studies in a hasty manner.

4. RELATION MODEL BETWEEN ENERGY EFFICIENCY AND INDUSTRIAL STRUCTURE TRANSFORMATION BASED ON MATHEMATICAL STATISTICS
4.1 Overview of Mathematical Statistics

The method of data statistics has been widely used in the research of data of various fields, which can help to further clarify the research results, in order to put forward effective suggestions and to improve the related system or programs (Tian, 2012). According to the field studied in this paper, in order to further clarify the relation between energy efficiency and industrial structure transformation, therefore, the regression analysis of mathematical statistics is employed. The so-called regression analysis is an effective method for measuring the statistical connection between two variables, which is widely used in many fields with a powerful effect.

4.2 Relation Model

The relations between the variables can be divided into two categories, one is certain and the other is uncertain. For some uncertain relation, when the independent variable is established, the dependent variable value does not change along with it, and the relation between the two can be expressed as \(Y = f(x) + \varepsilon, f(x)\) is the established function named as the regression function; \(\varepsilon\) is the random item, \(\varepsilon \sim N(0, \sigma^2)\). If the simple linear regression model is established as \(Y = \theta_0 + \theta_1x + \varepsilon\), with the data value \((x_i, y_i)\) \((i = 1, 2, ..., n)\), it will have \(y_i = \theta_0 + \theta_1x_i + \varepsilon_i, j = 1, 2, ..., n\) and suppose the residual error \(\varepsilon_i \sim N(0, \sigma^2)\). The equation of regression line is established by least square method as \(y = \theta_0 + \theta_1x\), positional parameter \(\theta_0\) and \(\theta_1\) the sum of squares of residues is as \(Q(\theta_0, \theta_1) = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} [y_i - (\theta_0 + \theta_1x_i)]^2\); when it reaches the minimum value, it has \(\frac{\partial Q}{\partial \theta_0} = 0, \frac{\partial Q}{\partial \theta_1} = 0\) then it has \(\theta_1 = \frac{\sum_{i=1}^{n} y_i x_i - \sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i^2 - n \sum_{i=1}^{n} x_i}, \theta_0 = y - \theta_1 x\), among them, \(x = \sum_{i=1}^{n} x_i, y = \sum_{i=1}^{n} y_i, R_{xx} = \sum_{i=1}^{n} (x_i - x)^2, R_{xy} = \sum_{i=1}^{n} (x_i - x)(y_i - y)\). At the same time, with \(R_{xy} = \sum_{i=1}^{n}(y_i - y)^2, P = \sum_{i=1}^{n}(\theta_1 + \theta_1 x_i - y_i)^2 = \frac{R_{xy}^2}{R_{xx}}, \) and the regression sum of square as \(P + Q = R_{yy}\), it further judges that whether there is so-called linear relation between the variable y and variable x. It needs to resort to the hypothetical test as \(G_0, \theta_1 = 0\), to choose the statistic volume as \(U[H > Ha(1, n - 2)]\) and to make the conclusions as follows.

If \(H > Ha\), it has to deny \(G_0\), so there is linear relation between the variable y and variable x. There is a direct relation between energy efficiency and industrial structure transformation through this model. Since there are four industries, and there are many factors in each industry, it needs to use the multiple regression models for analysis of the relations between a random variable and a set of variables (Zou, 2009). It sets the random variable \(Y\) and the number of m variables \(x_1, x_2, ..., m\). The relation \(Y = \theta_1x_1 + \theta_2x_2 + ... + \theta_m x_m + \sigma\), and \(\sigma\) is a random item, and \(\sigma \sim N(0, \delta^2)\). It is written as,

\[
Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, \quad X = \begin{bmatrix} 1 & x_{11} & ... & x_{1m} \\ 1 & x_{21} & ... & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & ... & x_{nm} \end{bmatrix}_{n \times (m+1)}
\]

\[
\sigma = \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \vdots \\ \sigma_n \end{bmatrix}, \quad \theta = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_m \end{bmatrix}
\]

(1)

\(y_i\) is the observation value of the random variable \(Y\) and \(X\) is the known Constant matrix, and the set of observation value of \(x_{1i}, x_{2i}, ..., x_{mi}\) \((i = 1, 2, ..., n)\) and the residual \(\sigma \sim N(0, \delta^2)\), so there is \(y = x\theta + \sigma\), sum of squares of residues is \(Q = \sigma^T \sigma = (y - x\theta)^T(y - x\theta)\).

The problems all comes down to that it can work out \(\theta\) based on \(y\) and \(X\), and achieve the minimum value of sum of squares of residue \(Q\).

5. CONCLUSIONS
The scientific rationality of the industrial structure directly affects the economic development, the overall level of the economy, the economic activities of the region and the core competitiveness between the regions, thus determining the economic market integration, coordination and sustainable development. It should use effective resources fully and rationally to adjust the consumption structure of resources and the economic upward trends. The optimization of industrial structure is one of the core elements. The different industries, because of their own large different characteristics and the different demands of the energy, need industrial restructuring and transformation which can make the energy consumption ratio of coal, oil, natural gas, water and other aspects of energy consumption and the overall value of energy efficiency consumption also change along with it. In addition, the differences in various categories of energy consumption will have a different degree of promotion or hindrance to the development of various industries. Based on this, the study of the relation between energy efficiency and industrial structure transformation will help the public to understand the unique economic growth function of different periods of economic development. Only to fully establish the relation between energy efficiency and industrial structure, it can more accurately grasp the direction of industrial restructuring, to develop more detailed plans to fully optimize the industrial structures, to strengthen the emphasis on energy utilization, and to effectively improve the efficiency of energy utilization, co-contributing to promoting the further development of China's economy.

REFERENCES

Tian Y.X.(2012). Research on the influence of industrial structure change on energy consumption in Hebei province, Shijiazhuang University of Economics,(06), 68-73.