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Variable Parameter Model to Analyse the Factors of Energy Efficiency Improvement in China

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Abstract: As an important factor supporting economic development, energy is an important tool for the survival and development of human society. Reducing the source and environmental problems caused by excessive use of energy has become one of the most important problems that people need to solve quickly in the 21st century. Many countries in the world have incorporated energy efficiency(EE) into their strategic decisions. EE has become a major factor in the global system competition in the new era. Based on the variable parameter model(VPM), this paper analyses the factors that improve China's EE. The energy consumption(EC) in China and the main factors affecting EE are briefly analysed; This paper puts forward a VPM, combines it with China's EE, analyses the factors to improve EE, and puts forward suggestions to improve EE.

1. Introduction

Improving EE is crucial to the implementation of sustainable development strategies. Energy is a long-term factor affecting the development of our national economy. The main energy problem in China is low personal EC and high energy intensity. Coal based energy system leads to serious environmental problems, power shortage of agricultural products and backward energy technology. To overcome the energy constraints that restrict China's economic and social development, we should further improve EE, change the state of economic development, and significantly reduce the dependence of economic development on energy. EE is crucial to the realization of China's strategic goal of modernization. Therefore, based on the VPM, this paper analyzes the factors that improve China's EE.

EE is a vital "source of energy". Improving EE is an important strategy to reduce dependence on energy and reduce greenhouse gas emissions. At present, China is facing great pressure to achieve the goal of energy conservation and emission reduction. How to improve EE and promote the rapid realization of the goal of energy conservation and emission reduction is the key problem we are

facing at present. Technological progress is a very important means to improve EE. Domestic independent research and development can promote the improvement of technological progress, but as a developing country, China relies more on the important channel of international trade technology spillovers to improve China's overall technological level [1].

Based on the analysis of the differences among regions and industries in China, it is necessary to seek new solutions to improve the EE of regions and industries. China's economy is in the period of rapid growth and the medium-term stage of industrialization. The industrial industry, especially the heavy industry, has an increasingly urgent demand for EC. The goal of reducing EC per unit of GDP by about 20% within five years is facing severe challenges. Therefore, it is necessary to improve EE and reduce EC from various regions and industrial industries [2-3].

2. Analysis on the Factors of Improving EE in China

2.1. Analysis of China's EC

With the advancement of industrialization and the rapid development of economy, China's EC is increasing rapidly. Figure 1 shows the trend of EC in recent years. In 1991, the total energy production was 1.048 billion tons of standard coal, an increase of 124.57% over 1991; The net increase was 1.618 billion tons of standard coal, an increase of 155.9% over 1991. In 2007, the energy supply and demand gap reached more than 300 million tons of standard coal. To make up this gap, we need to import energy from abroad. China is increasingly dependent on source imports, and this problem is difficult to solve in the short term [4-5].

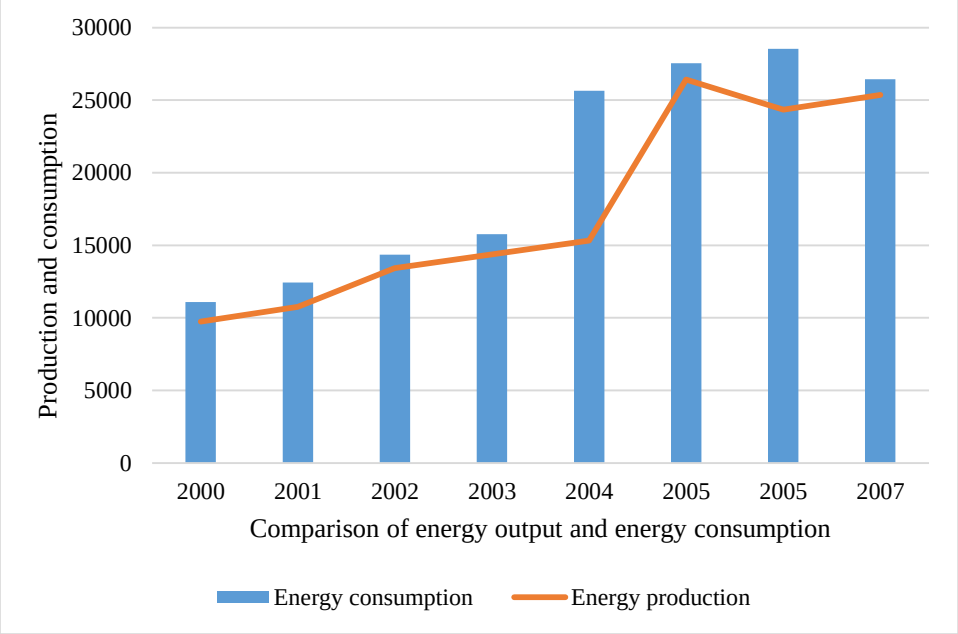

Figure 1. Comparison of energy output and EC

In 2006, it was 1.43 tons of standard oil / person; In Canada, 7.97 tons of standard oil / person and 8.27 tons of standard oil / person respectively; In the United States, 7.94 tons of standard oil / person and 7.74 tons of standard oil / person respectively; Japan has 4.09 tons of standard oil per person and 4.13 tons of standard oil per person respectively. On the whole, although China's per capita energy supply is gradually increasing every year, it is far below the level of the world's

developed countries [6].

2.2. EE

EE includes energy technology and energy economic planning. Technology empowerment mainly refers to the EE determined by manufacturing process, manufacturing process and technology application. Improving energy technology is usually related to simplifying manufacturing processes and processes, the application of advanced technology and manufacturing processes, and technological innovation and innovation. The economic performance of energy mainly refers to the role of economic factors such as economic development level, industrial system, cost level, control level, degree of opening to the outside world and economic system on energy use [7-8].

Energy intensity: the common usage is EC per unit of GDP. EC per unit of GDP refers to the capacity of a country or region to produce a proportion of GDP at a time. The calculation formula is:

$$\text{EC per unit of GDP}=\frac{Total\ energy\ consumption}{gross\ domestic\ product}$$

Energy productivity: the most commonly used form is "GDP energy". It is reciprocal with the EC per unit of GDP. It is a supplement to the analysis of traditional capital productivity and labor productivity, and can be used as an indicator to measure the EE of countries, regions or departments.

Total factor EE: because energy utilization efficiency is affected by many factors, each of which has a different degree of effect on energy utilization efficiency. In this case, it is necessary to find out the main factors affecting energy utilization efficiency and find effective ways to improve EE. Therefore, this chapter takes the EC intensity(ECI) as the evaluation index of EE, decomposes it by using the VPM method, and quantitatively analyzes the effect of various factors on the change of ECI [9-10].

2.3. Main Factors Affecting EE

Industrial structure: from the industrial level, different types of industries bring different levels of EC. Generally speaking, on the premise of creating the same output value, the tertiary industry has the lowest EC level, followed by the tertiary industry, and the EC of the secondary industry, which is dominated by heavy industry and high-EC industry, is far higher than that of the primary and tertiary industries. Therefore, the industrial structure has an important impact on EE. If we see that industries with low EE account for a large proportion of the whole national economy, the EE of the whole country will be at a low level [11]. With the reform and opening up, China has entered the era of industrialization, with rapid economic growth, rapid expansion of industrial scale, an increasing proportion in the national economy, a substantial increase in EC, and a decline in EE. When the degree of social and economic development reaches the developed level, the elasticity of product demand will gradually decrease, and at this time, the proportion of industry in the economy will gradually decrease [12].

Technological progress: the impact of technological progress on EE can be reflected through the impact on energy production or EC sectors. First of all, technological progress promotes the innovation of energy use technology, improves the utilization rate of energy, and can further promote the improvement of the production efficiency of various industrial sectors that use these energy for production [13]. It includes two levels, one of which is reflected in the equipment of the

industrial sector. The improvement of energy utilization enables the equipment to improve its production efficiency on the basis of efficient energy and water. The improvement of production efficiency will make the equipment in the industrial sector continuously reduce its own EC in the process of producing unit products. The second level is what we call the reduction of EC in the intermediate link. Secondly, in terms of energy production, the invention and innovation brought by technological progress can promote the efficiency of energy producers [14-15].

Energy structure: the EE of different energy sources is different. Using less high calorific value energy can produce the same output value as more low calorific value energy. Therefore, the consumption structure of energy has a great impact on EE. As we all know, coal is a kind of energy with high pollution and low efficiency. Due to the low efficiency of coal, under the premise of producing the same output value, the consumption of oil and natural gas is much lower than that of coal [16]. At present, developed countries have begun to gradually use oil and natural gas to replace coal. Oil and gas play a major role in the EC structure, and EE has been significantly improved [12]. In China, coal still accounts for a large proportion of EC due to its large reserves, relatively easy exploitation and low price. The EC structure is seriously uneven. Therefore, China's EE is lower than that of countries dominated by oil and natural gas. However, with the progress of technology and the adjustment of industrial structure, especially the continuous development of the tertiary industry, The exploitation and utilization rate of high-quality energy such as oil and natural gas will increase significantly, the use of coal will be reduced, and the EE will also be improved [17-18].

3. VPM Design

In this paper, the VPM method is used to decompose EC, trying to find an effective way to improve EE. VPMs are divided into variable coefficient and variable intercept.

The energy intensity is decomposed by the logarithmic average Di exponential decomposition method in the form of multiplication. Let F, H and K represent gross domestic product (GDP), total EC and ECI, and respectively represent sector categories and energy types, i and j respectively represent the consumption and EC structure (EC share) of class energy in the ith sector, and F_{ij} and FS_{ij} respectively represent EC, added value, energy intensity and industrial structure (industry added value share) of the ith sector.

ECI can be expressed equivalently as:

$$K = \frac{H}{F} = \sum_i \sum_j FS_{ij} \cdot K_i \cdot S_i \tag{1}$$

$$K_{ij} = FS_{ij} \cdot K_i \cdot S_i \tag{2}$$

Let ΔK、ΔK_{fks}、ΔK_{tec}、ΔK_{str} and respectively represent changes in energy intensity caused by changes in energy intensity and changes in energy structure, technological progress, and industrial structure, then:

$$\Delta K = K_t - K_{t-1} = \Delta K_{fks} + \Delta K_{tec} + \Delta K_{str} \tag{3}$$

3.1. Data Collection and Processing

According to the research purpose of this chapter and the availability of data, the required data include gross domestic product (GDP) f and total EC H: the added value of each sector F_i, EC H_i:

the consumption of each energy in each sector H_{ij}.

GDP and added value of all sectors: as China is in the stage of rapid industrialization, industry plays a major role in the whole national economy, and the EC of the industrial sector plays a decisive role in the EC of the whole country. Therefore, this paper lists industry separately and divides the whole national economy into six sectors. The gross domestic product and the added value of various sectors are calculated by the national gross domestic product index and the value-added index of sub industries, which take the year as the constant price.

3.2. Empirical Analysis of Factor Decomposition

According to the above formulas (1), (2) and (3), the contribution rate of the change of energy structure to the change of ECI, the contribution rate of technological progress to the change of ECI and the contribution rate of industrial structure adjustment to the change of ECI can be calculated respectively, which represents the change of total ECI. The change of ECI is negative, and the ECI decreases, and the energy utilization efficiency increases. A positive change indicates that the ECI increases, and the energy utilization efficiency decreases. The results are shown in Table 1 and Figure 2.

Table 1. Data sheet of energy intensity change factors at different times

Particular year	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
ΔK_{fks}(%)	0.07	0.048	0.020	0.47	0.73	0.015	0.28
ΔK_{tec}(%)	87.58	167.96	128.97	115.31	87.04	76.44	80.03
ΔK_{str}(%)	12.97	-68.64	-28.97	-15.85	13.06	23.55	18.78
ΔK_{tot}(Tons of standard coal / 10000 yuan)	0.279643	-0.035463	-0.143678	-0.259766	-0.248645	-0.167864	-0.185432

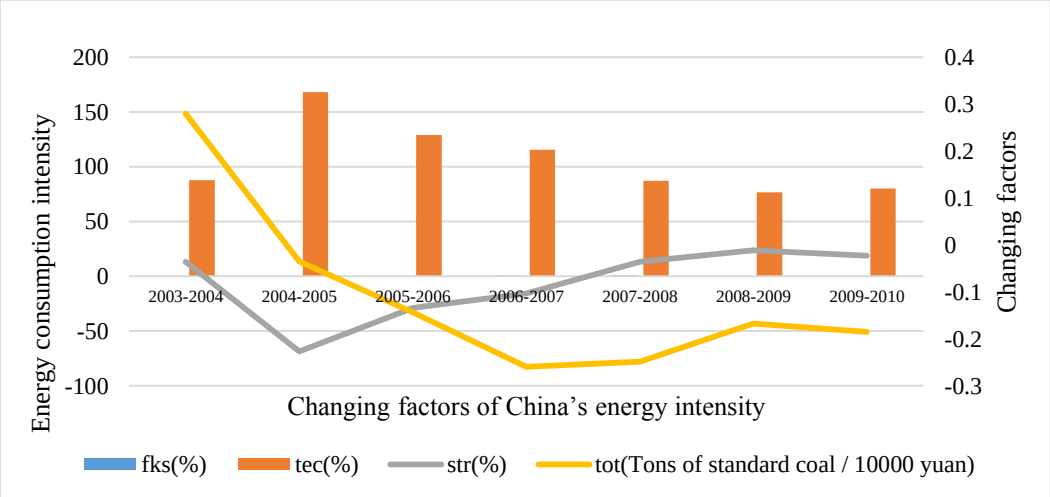

Figure 2. Changing factors of China's energy intensity

We can clearly see that among the three factors affecting ECI, technological progress played the largest positive role in the decline of ECI from 2003 to 2010, with a contribution of 102.3%. In contrast, the contribution of energy structure to the decline of energy intensity in the industrial sector is relatively small, basically changing within the range of 0-1%, with an average contribution of, indicating that China's energy structure has not changed much in recent years. Optimizing the energy structure and developing new energy to replace fossil energy have great potential to reduce ECI.

Through calculation, we can get the overall ECI of China and the ECI of various industries, as shown in Table 2 and figure 3. From 1996 to 2010, China's total ECI decreased significantly, which shows that in recent years, the EE of various industries in China has been continuously improved, the technological innovation in the energy field has also greatly improved the utilization rate of energy, and the phenomenon of energy waste has been significantly improved, Various energy-saving and emission reduction measures have played an obvious role, thus making the energy intensity achieve a significant decline.

Table 2. ECI of different industries

	1996	1998	2000	2002	2004	2006	2008	2010
Industry	17.35	14.95	7.12	6.42	5.35	5.13	4.96	4.64
Agriculture	4.06	3.96	3.84	3.77	3.47	3.56	3.23	3.03
Construction	3.18	3.05	3.01	2.94	3.04	3.25	2.98	2.87

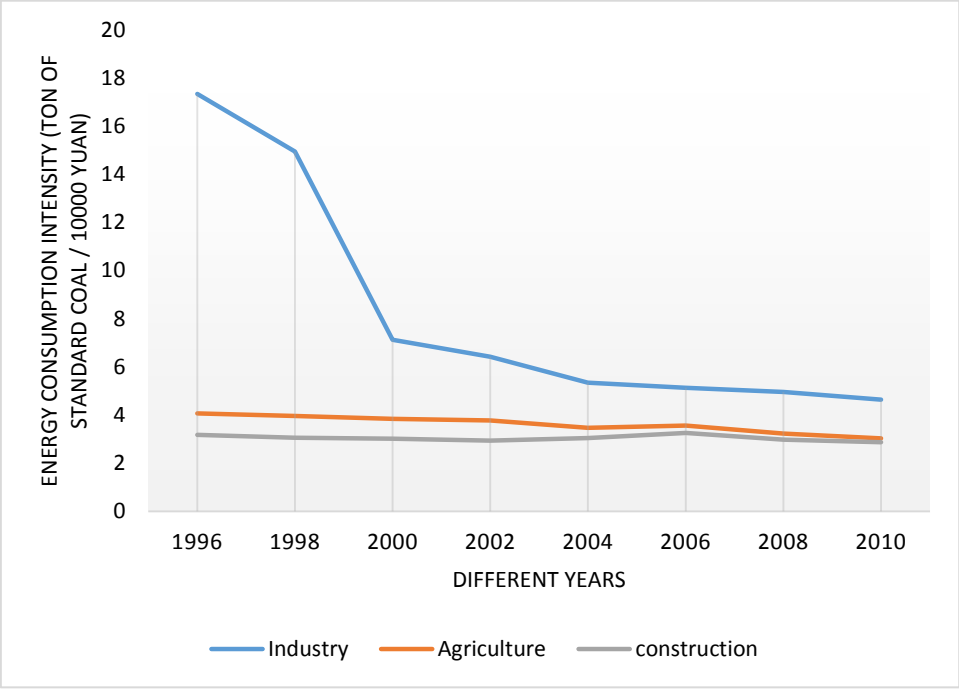

Figure 3. ECI by industry (tons of standard coal / 10000 yuan)

From the perspective of industries, it can be found that the industrial energy intensity is the highest, and the overall change of energy intensity is basically consistent with the change trend of industrial energy intensity. This is because industry has always been an industry with relatively large EC, especially steel, non-ferrous metals, chemical industry and other industries, which are

very energy dependent and belong to high energy consuming industries. However, the EC of these industries is relatively large, accounting for a large proportion of the total EC, which leads to the high overall energy intensity of our country. From 1996 to 2010, the energy intensity of industry decreased significantly, which also shows that the measures of energy conservation and emission reduction and elimination of backward production capacity in the industrial field are very effective, the EC is gradually reduced, and the use efficiency is getting higher and higher.

4. Suggestions for Improving EE

Promote technological innovation and progress and improve EE

For the advantages of foreign technology and hardware equipment, we should study hard, actively absorb and digest, and turn foreign technology and equipment into our own technology and equipment, so as to promote the continuous improvement of China's EE and reduce EC; In addition, some production technologies, production processes and production equipment with high EC and heavy pollution will be eliminated to improve the overall level of technological progress and effectively reduce the intensity of EC.

First of all, we should reduce the proportion of coal consumption and improve the utilization efficiency of coal. Coal is a kind of energy with low efficiency and high pollution. Reducing the consumption proportion of coal has a significant impact on improving EE. However, based on the current situation of "more coal and less oil" in China, coal will still account for a large proportion for a period of time. Therefore, while reducing coal consumption, we should increase technological investment and innovation in coal utilization, vigorously develop and utilize clean coal, and improve the utilization efficiency of coal; Secondly, the proportion of oil and natural gas consumption should be increased. The development level of natural gas in China is not high, and the utilization of natural gas has great potential. Therefore, we should vigorously develop and utilize natural gas and improve the replacement ratio of natural gas to coal; Finally, we should vigorously develop new energy. Under the realistic conditions of energy shortage and increasing pollution, we should strengthen the development intensity and utilization scope of these new energy sources, such as renewable and clean energy such as wind energy and solar energy, and constantly reduce the polluting energy such as coal, so as to gradually reduce EC and environmental pollution.

Improve the energy market price regulation system and reduce energy intensity

We can use macro-control to promote enterprises to consciously reduce energy waste, improve energy utilization, and even develop new renewable energy to replace this kind of energy. On the other hand, the role of price mechanism will enable enterprises to increase investment in the field of technology, improve the technical level of enterprises, so as to improve the technology of energy use, so that unit EC can produce more output value. However, the current energy market mechanism in China is not perfect. The price of oil and other energy does not fully reflect the scarcity of this energy, and the use of new energy is also very low. The state should hope for long-term development in the future, adjust the price formation mechanism in the energy field, so that the energy price can truly reflect the scarcity and importance of this kind of energy, so as to guide enterprises and consumers to consciously start saving energy. At the same time, it should promote new energy on a large scale and reduce the use of new energy. In this way, both enterprises and consumers, under the guidance of the price mechanism, will shift from high wood disposable energy to low wood new energy, and eliminate high EC industries, so as to optimize industrial institutions and further reduce energy intensity and EC.

Appropriately levy energy taxes to improve energy utilization

At the economic level, EC can also be adjusted by means of taxation. The collected energy tax can be widely used to subsidize and support enterprises that adopt new energy or consciously carry out energy technology research and development, encourage their behavior, and can pool a large amount of funds to further develop energy use technology from a domestic perspective, so as to improve EE. A higher level of energy tax should be charged for high-EC industries, and low-energy and new energy enterprises should be subsidized at the same time to support the research of energy development technology and practical technology.

5. Conclusion

This paper uses the VPM to study the factors that improve China's EE, but due to the limitations of subjective and objective conditions, the research of this paper still has the following shortcomings: due to the limitations of research data, due to the limitations of objective conditions, the time of the research sample cannot be extended to the last two years. In order to keep the consistency of research time, with the continuous updating of data in the future, we will further overcome the limitations of data and expand the research scope in time; Lack of research perspective. Considering whether export trade technology spillovers promote a country's technological progress has not formed a unified conclusion in the academic circles, generally speaking, technological progress and labor productivity are often improved through import trade technology spillovers, so in the future research, we will study the impact of Technology Spillovers on EE from the perspective of export trade, so as to make up for the lack of research in this regard in this paper; In short, the factors that improve China's EE need further research.

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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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