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PERFORMANCE EVALUATION OF CO2 EMISSIONS REDUCTION IN THE 12TH FIVE-YEAR-PLAN OF CHINA

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ABSTRACT

With the growing threat of global climate change, energy savings and CO2 emissions reduction have become a major long-term issue faced by China. For a more scientific analysis of energy savings and emissions reduction data of China, a modified logarithmic mean Divisia index (LMDI) approach is adopted. The modifications and the theoretical model of the approach are introduced in this paper. Based on China's economic development and energy consumption data during the 12th Five-Year-Plan period, quantitative assessment of effects of the energy savings and emissions reduction in the four key areas (namely energy conversion efficiency improvement, energy utilization efficiency improvement, primary energy mix adjustment and industrial structure adjustment) is carried out. The results and laws of energy savings and emissions reduction in the above areas during the 12th Five-Year-Plan period are summarized. Finally, combined with historical analysis and current situations, some suggestions for China's future work in the field of energy savings and emissions reduction are proposed.

Keywords: 12th Five-Year-Plan, energy savings and CO2 emissions reduction, modified LMDI approach; index decomposition.

1. INTRODUCTION

In the past half century, due to the increase in the global population, the enhancement of human economic activities and the development of modern industry, human society has become more and more energy-consuming. The massive use of fossil fuels and the reduction of forest area have led to a significant increase in the content of greenhouse gases, such as carbon dioxide which will cause great changes in the global climate. To cope with the increasingly severe climate change problems, the Chinese government attaches great importance to mitigating greenhouse gases emissions [1-4]. In 2009, it proposed a target of 40% to 45% reduction in carbon emissions per unit of GDP in 2020 [5]. At the same time, it proposed a target of 16% reduction in energy consumption per unit of GDP and a 17% reduction in carbon emissions per unit of GDP during the 12th Five-Year-Plan period [6]. All these strategies aim to promote energy savings and emissions reduction across the world and protect the environment we live on.

However, how to evaluate the contribution China has made in CO2 emissions reduction during the 12th Five-Year-Plan period and make scientific plans for future development in various fields to ensure energy savings and emissions reduction continue to be effective, is worthy of scientific assessment and quantitative research. Therefore, a modified LMDI approach is used to analyze the economic development and energy consumption data during the 12th Five-Year-Plan period in this paper. Quantitative assessment of the effectiveness of energy savings and emissions reduction in the four key areas (namely energy conversion efficiency improvement, energy utilization efficiency improvement, primary energy mix adjustment and industrial structure adjustment) is carried out. Based on the results of the analysis as well as the historical experience and current developments of China, some suggestions are given on the development of the key areas in the future.

2. APPROACH AND MODEL

2.1 Modified LMDI approach

In the traditional Kaya identities, the index of primary energy intensity is used to decompose CO2 emissions [7-10]. As energy conversion efficiency depends on energy-supplying sectors, it is difficult for the energy-use sectors to study the final energy intensity. To overcome the shortcomings of the traditional LMDI approach, Xu et al integrate the final energy conversion effect into the decomposition model [11], which makes it possible to assess the energy conversion efficiency of the energy supply side and energy utilization efficiency of the energy demand side at the same time. Based on their research, Yi et al modified the model by decomposing national energy intensity by primary fuel species in the first level and further decomposing the total energy conversion efficiency into the final energy mix efficiency and the final energy conversion efficiency in the second level by final fuel species [12]. Characterized with a multilevel decomposition procedure, this modification can meet the need of reflecting the effect of primary energy mix shift which is a significant aspect in emissions reduction analysis of China.

2.2 Modified LMDI model

In this paper, carbon intensity is decomposed into the following four parts: total energy conversion effect, primary energy mix effect, industrial structure effect, final energy intensity effect. Based on the way of decomposition, carbon intensity can be expressed as follows

$$CI^t = \frac{C^t}{GDP^t} = \sum_i \sum_j \frac{C_{ij}^t}{GDP^t} = \sum_i \sum_j \frac{C_{ij}^t}{PE_{ij}^t} \cdot \frac{PE_{ij}^t}{PE_i^t} \cdot \frac{PE_i^t}{FE_i^t} \cdot \frac{FE_i^t}{GDP_i^t} \cdot \frac{GDP_i^t}{GDP^t} = \sum_i \sum_j R_{ij}^t \cdot M_{ij}^t \cdot T_i^t \cdot I_i^t \cdot S_i^t \quad (1)$$

Where CI^t denotes the carbon intensity in the year *t*, FE denotes the terminal energy consumption; PE denotes the primary energy consumption; C denotes the carbon emissions; S_i^t denotes the GDP ratio of the *i*th industry in the year *t*; I_i^t denotes the final energy intensity of the *i*th industry in the year *t*; T_{ij}^t denotes the inverse of the total energy conversion efficiency of the *i*th industry in the year *t*; M_{ij}^t denotes the ratio of *j*th fuel type to total primary energy consumption in the *i*th sector in the year *t*; R_{ij}^t denotes the carbon emissions factor of *j*th fuel species in the *i*th sector in the year *t*.

As the conversion efficiencies of various final fuel species are different, the total energy conversion efficiency cannot fully reflect the change in the conversion efficiency of the energy production side. As mentioned above, the energy conversion efficiency is decomposed further into the final energy conversion effect and the final energy mix effect [11, 12]. The decomposition equation is shown in formula (2).

$$T_i^t = \frac{PE_i^t}{FE_i^t} = \sum_k \frac{FE_{ik}^t}{FE_i^t} \cdot \frac{PE_{ik}^t}{FE_{ik}^t} = \sum_k N_{ik}^t \cdot P_{ik}^t \quad (2)$$

Where the subscript k denotes various final fuel species; N_{ik}^t denotes the ratio of *k*th final fuel species to total final energy consumption in the *i*th sector in the year *t*; P_{ik}^t denotes the inverse of the energy conversion efficiency of *k*th final fuel species in the *i*th sector in the year *t*.

The illustration of the modified LMDI model is shown below.

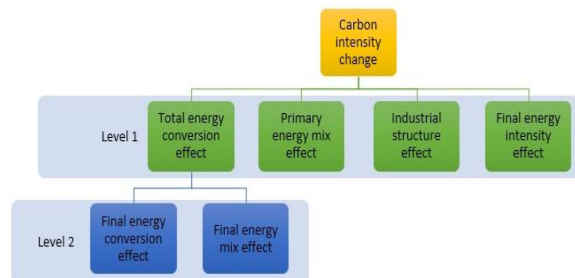

Fig. 1. Illustration of the modified LMDI model

2.3 Studied industries and energy species

This paper selects all the economic and residential industries as research objects, including twenty-five economic industries and one residential industry. The value-added data of various industries comes from the China Statistical Yearbook and the National Bureau of Statistics [13]. The energy consumption data of various industries comes from the China Energy Statistics Yearbook [14].

Four primary energy species (coal, oil, natural gas, non-fossil fuels) and six final energy species (coal, coke, petroleum, natural gas, electricity, and heat) are studied in this paper. Carbon emissions from heating and power generation are distributed to various industries based on their heat and electricity consumption ratios. Five kinds of energy conversion efficiency are considered, which are coal washing, coking, petroleum refining, thermal power and heating supply. The data is all from the China Energy Statistical Yearbook [14].

3. RESULT ANALYSIS

In 2010-2014, the carbon intensity decreased by 15.8% among which the final energy intensity effect, resulting in a 14.7% reduction in carbon intensity, is the most important driving factor for emissions reduction. The primary energy mix effect and the final energy conversion effect are the other two key emissions reduction driving factors, resulting in a 2.7% and 1.9% reduction in carbon intensity respectively. The industrial structure effect has a reverse effect on the reduction of carbon intensity which leads to a 0.1% increase in carbon intensity, but the impact is small relatively. The overall analysis results are shown in the figure below.

3.1 Final energy intensity effect

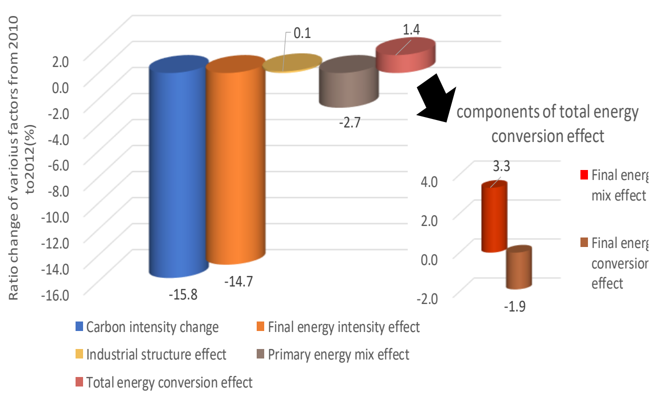

Fig. 2. Analysis results of data during the 12th Five-Year-Plan period

The continuous improvement of energy-consuming efficiency in some key industrial sectors is the most important driving factor for the decrease of carbon emissions per unit of GDP during the 12th Five-Year-Plan period. The contribution of these sectors is even far more than the sum of the other factors. These key energy-consuming industries are mainly concentrated in industries such as steel, cement, caustic soda, electrolytic aluminum, etc.

From the departmental level, the final energy intensity of petroleum processing, coking, chemical, power gas supply, transportation, construction and other industries dropped by less than 12%, which is far from the international standards and the energy savings goals in the 12th Five-Year-Plan. The final energy intensity of light industry such as food and papermaking has dropped significantly by 20%, which has exceeded its energy savings goals.

3.2 Industrial structure effect

From the late stage of 12th Five-Year-Plan period, the main driving factor for promoting carbon emissions reduction has gradually shifted from the efficiency improvement to the structural adjustment. Although the 12th Five-Year-Plan proposed the transformation of industrial structure to service industry and light industry, the actual effect is not obvious. Excluding the impact of inflation, the service sector accounted for only 44.5% of GDP in 2014. It shows no significant increase compared with the ratio of the year 2010 (see Table 1). In addition, the proportion of value-added of light industry has hardly changed, which indicates that the restructuring of the tertiary industry is still slow and does not get the expected results in emissions reduction. According to estimates, industrial restructuring has not only played a role in reducing carbon intensity, but has led to a slight increase in carbon intensity by 0.1%.

Table 1. Ratios of value-added of various industries

	Actual value in 2010	Actual value in 2014	Value in 2014 (constant price in 2010）
Primary industry(%)	9.5	9.1	8.2
Secondary industry(%)	46.4	43.1	47.3
Tertiary industry(%)	44.1	47.8	44.5

In the first four years of the 12th Five-Year-Plan, the overall coordination of industrial restructuring between industrial sectors was poor. During this period, the value-added of steel, electricity, petroleum processing, coking and other high energy-consuming industries fell by 9.3%, but the value-added of other high-energy-consuming industries, such as cement, chemical and non-ferrous metals, rose by 9.7%, which indicates that the essence of industrial structure changes is the internal adjustment between heavy industry sectors and does not bring about total emissions reduction.

3.3 Primary energy mix effect

In 2010-2014, the primary energy mix effect became the second largest emissions reduction driving factor after the final energy intensity effect. From this point of view, energy structure transformation is the key prerequisite for realizing China's peak carbon emissions in 2030. The primary energy structure has gradually shifted from coal to non-fossil fuels and natural gas. Among them, the use of non-fossil fuels represented by hydro power and wind power has made a great contribution to the reduction of carbon intensity.

3.4 Energy conversion effect

Although the total energy conversion effect caused the carbon intensity to increase by 1.4%, it was found that the real factor that led to the increase in carbon intensity by 3.3% was the change in the final energy structure after decomposing the total energy conversion efficiency into the final energy structure efficiency and the final energy conversion efficiency. Since 2010, the ratio of power consumption has been increasing, but the conversion efficiency of thermal power generation is much lower than other energy species. Consequently, this structural change has a negative effect on the reduction of carbon intensity.

In contrast, improving energy conversion efficiency has played an important role in reducing carbon intensity, resulting in a 1.9% reduction in carbon intensity. Especially in the thermal power industry, due to technological innovations and the shutdown of small thermal power plants, the efficiency of thermal power generation has greatly improved and its contribution has accounted for about 90% of the contribution of all energy species.

4. SUGGESTIONS

Based on the above analysis and conclusions, combined with China's current situations, the following suggestions can be given on the energy savings and emissions reduction work for the future of China.

Firstly, fully tap the energy-saving potential of the key energy-consuming industries. Develop efficient and practical energy savings and emissions reduction technologies and improve energy efficiency standards.

Secondly, increase the actual proportion of the value-added of the tertiary industry. Accelerate the innovation of service products and business modes and explore the integration of productive services and strategic emerging industries.

Thirdly, keep popularizing and developing the non-fossil energy (hydropower, wind power, photovoltaic power and nuclear power, etc.) and accelerate the development of unconventional natural gas (shale gas, tight gas, etc.) to promote the transformation of energy structure to low carbonization.

Finally, increase the proportion of large generator units. Promote the construction of natural gas combined cycle (NGCC) technology and the natural gas cogeneration system to tap the emissions reduction potential of energy conversion.

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