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Decomposition Analysis of CO_2 Emission in China's Electric Power Industry

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Abstract. The electric power industry is a largest contributor to fossil energy consumption and CO_2 emissions in China. The LMDI-I method was selected and used to conduct the study in this paper. Decomposition analysis shows that the economic scale is the most important factor that affecting the electric power industrial CO_2 emission among the seven factors studied in this paper, the effects of the electricity consumption scale and energy structural factors also plays a significant role in increasing CO_2 emission. The generating efficiency factor and the ratio consumption to generation factor have played a key role in reducing CO_2 emissions. Finally, based on the results the constructive suggestions to reduce the CO_2 emissions has been put forward.

1. Introduction

The electric power industry is a largest contributor of all the industries to fossil energy consumption and carbon emission. China's electric power industrial CO_2 emissions accounted for 48.86% and 13.72% of the total CO_2 emissions in China and the world's energy combustion [1]. Therefore, for the purpose of achieving China's energy conservation and emission reduction targets, the electric power industry should bear the primary responsibility of reducing consumption and reducing emission and acting as the main force of CO_2 emission reduction.

There are many decomposition techniques available for environmental and energy literature. Two of the most common methods of decomposing energy consumption are structural decomposition analysis and index decomposition analysis. There are many types of index decomposition analyses methods, including the Divisia, Fisher, Laspeyres, and Paasche methods. According to the research by Liu and Ang [2] and B.W. Ang [3, 4], the average value of the index (LMDI), the logarithmic mean Divisia index) is a better way to avoid decomposition of any other factors' residuals. There are two main forms of LMDI in applications: LMDI-II and LMDI-I. Ang and Liu [5] noted the consistency of these two methods: in the decomposition process, with the gradual increase of the level of decomposition, the decomposition method should be able to ensure the consistency of results from the decomposition levels. Comparing the results of the LMDI-II methods and LMDI-I, it was found that only the LMID-I method can guarantee consistency. In summary, based on the existing research on index decomposition analysis method, this paper chooses LMDI-I method for research.

The decomposition model of LMDI has been successfully applied in the field of carbon emission and energy decomposition by a lot of foreign and domestic scholars in recent years. For instance, energy consumption of the EU's 27-member states was analyzed using a LMDI decomposition model by P. Fernández González et al. [6]. Additionally, Zhao et al. [7] used this model to decompose the urban residential energy consumption in China, and Sorrell et al. [8] analyzed the UK's transportation energy consumption with the LMDI model.

The paper takes electric power industry of China as an example, the changes in electric power of China industrial the main factors and carbon emissions affected the industrial CO_2 emissions are analyze through a series of data and models, while some comments and suggestions on the current problem will also be made in the paper.

2. Methodology

2.1. Improved LMDI decomposition model

In the paper, the LMDI model has improved. The total effect is divided into seven parts: the effect caused by the energy structural adjustment is represented as ΔC_{es}; the effect resulted from the changes in generating efficiency is represented as ΔC_{cr}; the effect resulted from the changes in electric power industry structural adjustment is represented as ΔC_{s}; the effect resulted from the ratio power consumption to generation is represented by ΔC_{r}; the effect which is caused by the scale of electricity consumption is represented as ΔC_{ec}; the effect which is caused by the scale of economy is represented as ΔC_{y}; and the effect resulted from the Carbon dioxide emission factors is represented by ΔC_{emf}. As a result, the model can be expressed as follows:

$$\Delta C_{\mathrm{tot}} = \Delta C^T - \Delta C^0 \tag{1}$$

$$\Delta \mathrm{C_{tot}} = \Delta C_{es} + \Delta C_{cr} + \Delta C_s + \Delta C_r + \Delta C_{ec} + \Delta C_y + \Delta C_{emf} \tag{2}$$

$$\Delta \mathrm{C_{es}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(ES_i^T/ES_i^0) \tag{3}$$

$$\Delta \mathrm{C_{cr}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(CR^T/CR^0) \tag{4}$$

$$\Delta \mathrm{C_{s}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(S^T/S^0) \tag{5}$$

$$\Delta \mathrm{C_{r}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(R^T/R^0) \tag{6}$$

$$\Delta \mathrm{C_{ec}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(EC^T/EC^0) \tag{7}$$

$$\Delta \mathrm{C_{y}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(Y^T/Y^0) \tag{8}$$

$$\Delta \mathrm{C_{emf}} = \sum\nolimits_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0)\ln(EMF_i^T/EMF_i^0) \tag{9}$$

where, $\sum_{\mathrm{i}} \mathrm{L}(C_i^T, C_i^0) = (C_i^T - C_i^0)/\ln(C_i^T/C_i^0)$.

E^T represents the energy consumption of total energy consumption in year t, E_i^T represents the energy consumption of fossil energy type i in year t, TP^T represents the thermal power generation in year t, G^T represents the total power generation in year t, EC^T represents the total electricity consumption in year t, Y^T represents the GDP in year t, C_i^T represents the carbon dioxide emissions of energy i in year t, ES_i^T represents the energy consumption proportion of the total consumption of energy i in year t (E_i^T/E^T), CR^T represents the energy consumption per unit generating unit in thermal power production in year t (E^T/TP^T), S_i^T represents the thermal power production proportion of the total power production in year t (TP^T/G^T), R^T represents the ratio of the total power production and consumption in year t (G^T/EC^T), EMF_i^T represents the ratio of carbon emissions and energy consumption of energy I in year t.

2.2. Data source
The main basic data in this article comes from China Statistical Yearbook (2001-2016) [9], china Electric Power Yearbook (2001-2015) [10] and China energy Statistical Yearbook (2001-2016) [11]. The conversion coefficients for coal, oil and gas calculate based on industrial enterprise data, and an electric power conversion coefficient of 4.04 is used. The energy consumption is presented as an equal value (special circumstances will be described). Tons of standard coal abbreviated to tce. In this paper, the industrial output of 2000 is assumed a constant price in the LMDI model.

3. Results and discussion

3.1. Electric power industrial CO_2 emissions in China
CO_2 emission intensity refers to CO_2 emissions per unit growth of power generation. Figure 1 shows the CO_2 emissions and CO_2 emission intensity of electric power industry in the past fifteen years.

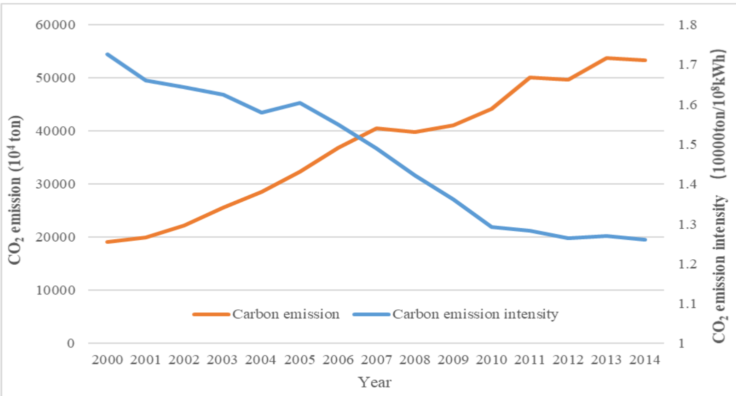


Figure 1. Variation of CO_2 emission and CO_2 emission intensity from 2000 to 2015, China.

As can be seen from Figure 1, the CO_2 emissions in the past fifteen years growing from 19126.82×104 ton in 2000 to 53259.98×104 ton in 2014, and the CO_2 emission in 2014 is higher than that in 2000, CO_2 emissions in 2014 has increased 178.46% at the level of 2000, with an average annual growth rate of 7.74%. The reason is that China's economy has experienced a rapid growth over the past 15 years, but rapid growth has also caused rapid growth in carbon dioxide emissions.

3.2. LMDI decomposition of electric power industrial CO_2 emission in different factors
In order to analyze the changes in electric power industrial CO_2 emission better, LMDI model is used to analyze decomposition of carbon dioxide emissions. The LMDI decomposition energy consumption model was applied and the data were substituted into formulas (1)-(9), and the results are shown in Figure 2. CO_2 emission factor is 0, because the CO_2 emission factor is a constant in practical application.

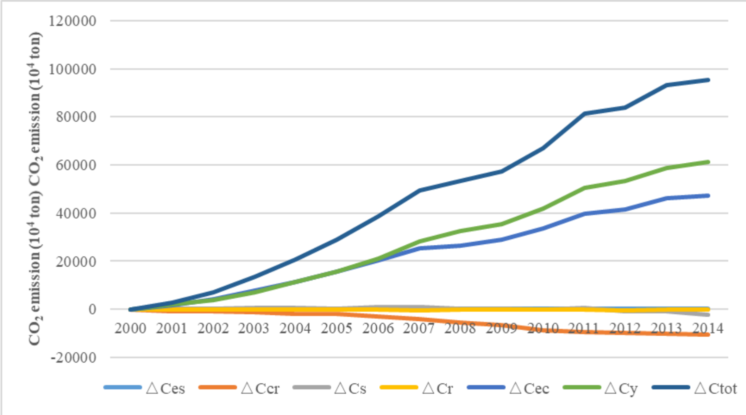


Figure 2. CO_2 emission decomposition from 2000 to 2014, China.

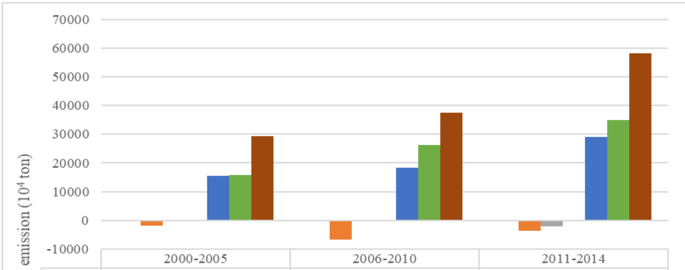
According to Figure 2, from 2000 to 2014, the factors of economic scale, power consumption, and energy structure are all positive effects. The efficiency of power generation and the consumption of power generation are negative effects. The factors of power industry structure change from positive to negative. As each effect value increases, the total effect of these six factors also increases. The results show that the three factors of economic scale, electricity consumption scale and energy structural continue to promote the growth of CO_2 emissions. In addition, the efficiency of power generation, the ratio consumption to generation and the power industry structure will promote the reduction of CO_2 emissions. The continuous expansion of economic scale is one of the main reasons for the increase of CO_2 emissions in China's power industry. From 2001 to 2014, economy of scale factor on carbon emissions contribution, the contribution rate showed an upward trend, the cumulative contribution of carbon emissions caused by China's industrial economies of scale changes by 64.18%, highlighting the economic scale factors is one of the decisive factors for power industrial CO_2 emission growth. The effect of electric power consumption factors on CO_2 emissions change is another major reason in CO_2 emissions for the increase in China's power industrial. However, it is less than the economies of scale effect on CO_2 emissions transform. From 2000 to 2014, the cumulative contribution of CO_2 emissions caused by the change of electric power consumption factors of degree was 49.59%.

3.3. LMDI decomposition of electric power industrial CO_2 emission in different factors

As shown in Figure 3, the variation of industrial carbon dioxide emissions can divide into two stages from 2000 to 2014.

The first stage: From 2000- 2007, the accelerated growth of the industrial CO_2 emissions. This is because of the rapid development of China's economy, which caused a continued expansion of economic size and power consumption, and led to the economy scale factors effect ΔCy and the scale of electricity consumption factors effect ΔCec grow fast, and these two factors effect takes a highly portion of the total effect, so the total effect ΔCtot increased.

The second stage: From 2008-2014, the total industrial CO_2 emissions grew relatively slowly. This is because that China issued a number of energy saving and emission reduction policies and adopted many energy-saving technological transformation measures. Therefore, the generating efficiency factor ΔCcr and the ratio generation to consumption factor ΔCr effect obviously, and the power industry structure factor ΔCs began to promote to reduce the CO_2 emission. Compared with the first phase, the effect of increasing energy consumption intensity was larger, and the total effect ΔCtot grew relatively slowly. The results show that the generating efficiency and the ratio consumption to generation played an important part in the suppression of the total industrial CO_2 emissions.



	2000-2005	2006-2010	2011-2014
△Ces	7.309148912	179.4417495	151.0484254
△Ccr	-1862.510301	-6725.791743	-3671.359373
△Cs	167.6705388	-236.3021712	-2116.227305
△Cr	-175.7691188	-77.75652647	-181.1594392
△Cec	15487.31621	18234.96212	29016.34599
△Cy	15648.61179	26243.33344	34902.40456
△Ctot	29272.62827	37617.88687	58101.05286

Figure 3. CO_2 emission decomposition from 2000 to 2014 for different"five year", China.

4. Conclusion

Decomposition analysis shows that the economic scale is the most important factor affecting the electric power industrial CO_2 emission among the seven factors studied in this paper, the effects of the electricity consumption scale and energy structural factors also plays a significant role in increasing CO_2 emission. The generating efficiency factor and the ratio consumption to generation factor have a negative effect, and the power industrial structure factor change from positive to negative. Therefore, a sustained and rapid increase in industrial carbon emission can expect if the development mode of China power industry is consistent. Thus, to make a change that transforming the high-input and high-consumption growth mode to an energy-saving and environment-conscious mode is necessary.

Due to the recognition of the development of green economy in China and various regions and the importance of implementing energy-saving technological transformation, the generating efficiency factor and the ratio consumption to generation factor have played a key role in reducing CO_2 emissions. At the same time, the power industrial structure factor changed from positive to negative due to the adjustment of power industry structure.

Acknowledgments

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