Impact of Industrial Structure Adjustment on Carbon Emission Reduction and Analysis of Its Contribution Rate-Based on Kaya Identity and LMDI Model

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Abstract. China's carbon emissions have been increasing since the reform and opening up, this paper uses the LMDI decomposition model calculate and analyze influencing factors of China's carbon emissions based on the Kaya deformation identity, and analyzes the impact of industrial structure adjustment on carbon emissions, and the contribution rate difference of different industries for carbon emission, studies show that although the carbon slowing effect brought by China's industrial structure adjustment is not strong, it has certain results and impact, but there are differences in emission reduction effects in various industries.

Keywords: industrial structure adjustment; carbon emissions; Kaya identity; LMDI model.

1. Research Background

China is a responsible and committed major country, It has publicly announced that it will cut carbon dioxide emissions per unit of GDP by more than 40% in 2020, compared with 2005 levels. Under this background, China's main challenge is to explore ways to reduce emissions in order to achieve both economic development and low carbon, this paper combines industrial structural adjustment and carbon emissions to study accordingly, attempts to analyze and study carbon emissions from the perspective of industrial structure adjustment, in order to effectively control carbon emissions under the premise of stable and sustainable economic development, and achieve a win-win situation in which invaluable asset and lucid waters and lush mountains coexist.

In recent years, with the growing environmental pollution and energy crisis, etc., more scholars have begun to analyze the ways and effects of industrial structure adjustment on carbon emissions. At present, most scholars believe that the reasonable industrial structure can effectively suppress carbon emissions, such as Zhou Shaofu (2017) [1]. Some scholars have studied from different industries and believe that the secondary industry has the largest impact on carbon emissions, such as Han Jian et al. (2014) [2]. Therefore, on the basis of previous studies, this paper calculates and analyzes the influencing factors of China's carbon emissions, further explore the contribution rate of industrial structure adjustment for carbon emission reduction of different industries from a micro angle, this can effectively coordinate economic development and ecological environmental protection, and it is of great significance for achieving sustainable economic development.

2. Analysis of the Impact of Industrial Structure Adjustment on Carbon Emissions

2.1 Model Setting and Data Source

The principle of Kaya's identity is simple and easy to understand, its disclosed driving factors are also interpretable, observable, and controllable, its initial expression is:

$$S = \frac{S}{E}.\frac{E}{Y}.\frac{Y}{P}.P = f.e.g.p \tag{1}$$

In order to study the impact direction and degree of industrial structure adjustment on carbon emissions, this paper deforms on the basis of Kaya identity. The adjusted Kaya identity is as follows:

$$S=\sum_{ij} s_{ij}=\sum_{ij} Y.\frac{Y_i}{Y}.\frac{C_i}{Y_i}.\frac{C_{ij}}{C_i}.\frac{s_{ij}}{C_{ij}}=Y.P_i.PI_i.CI_{ij}.N_{ij} \tag{2}$$

i (i=1, 2, 3) represents the primary industry, secondary and tertiary industry; j (j=1,2,3 ...) represents primary energy, it is mainly coal, oil and natural gas, the selection and representative meaning of variables in carbon emission driving factor decomposition formula is as follows:

(1) S represents the total carbon dioxide emissions, S_{ij} represents the carbon emissions of j primary energy source of i industry;

(2) Y represents GDP, Y_i represents the output value of i industry, the unit is 100 million yuan;

(3) C_i is used to represent the total energy consumption of i-th industry, and C_{ij} is j energy consumption of i industry, the data are obtained from China Energy Statistical Yearbook;

(4) P_i is used to represent economic efficiency of industrial structure, and it is the ratio of industrial output value of i industry to GDP;

(5) PI_i is used to represent the energy consumption intensity of the industry, the specific algorithm is: energy consumption of i industry/ i industry output value;

(6) CI_{ij} is selected to represent the energy consumption structure ratio, namely C_{ij}/C_i*100%, N_{ij} represents the carbon emission coefficient of the j primary energy source in the i industry.

In order to investigate whether carbon emissions are affected by economic scale, industrial structure, etc., for the Kaya identity (formula 2) above, this paper chooses to use the LMDI model for decomposition. The decomposition method mainly refers to AngB. W (1998) [3] and Guo Chaoxian (2012) [4] and other scholars on the LMDI model, due to lack of space, we have omitted the decomposition process, and the decomposition results are as follows:

$$CEG=\frac{S_T}{S_0}=ETS.INS.IEI.SEC.EMC \tag{3}$$

In the above formula, ETS represents total economic scale, INS represents industrial structure, IEI represents industrial energy consumption intensity, SEC represents energy consumption structure, and EMC represents energy carbon emission coefficient, it is generally constant 1, S_O is the base period and S_T is the last period.

2.2 Empirical Results

The development of China's economy and the interval of the national five-year plan are combined, In order to more clearly see the changes in the study interval effect, this paper divides the measurement period into three sub-periods. On the basis of above, the impact of LMDI on China's carbon emissions influencing factor is disclosed in stages, as shown in Table 1.

Table 1. effect value of influencing factors of China's carbon emission (sub-interval)

index	symbol	measurement time		
		2006-2010	2011-2015	2006-2015
carbon emission growth rate	CEG	1.4974	1.0349	2.1901
economic size	ETS	1.9979	1.3871	6.3751
energy consumption intensity	IEI	0.8631	0.9129	0.3824
energy consumption structure	SEC	0.9937	0.9924	0.9913
industrial structure	INS	0.8739	0.8236	0.9063
carbon emission coefficient	EMC	1	1	1

Note: The data in this table are based on empirical calculations.

It can be seen from Table 1 above that during 2006-2015, the growth rate of carbon emissions in China was almost greater than 1, it means that the overall emissions are still increasing, and the overall increase is 2.1901 times. Among them, the effect value caused by the total economic factor is 6.3751, it is also the main reason for the increase of carbon emissions; the effect value of carbon emissions caused by the industrial structure adjustment, energy structure, and energy consumption structure are all less than 1, namely the three factors have an inhibitory effect on carbon emissions. The industrial structure adjustment as the key research factor in this paper, its effect value is less than 1 but close to 1, it shows that industrial structure adjustment has a negative impact on the increase of total carbon emissions, but the effect is relatively small, namely changes in the industrial structure will curb the continuous increase of carbon emissions, which is conducive to carbon reduction, but the effect is not obvious. It can be understood that there are inter-industry and intra-industry optimization and upgrades, which further reduce carbon emissions, this conclusion provides both data and antecedent support for the next model studying the impact and contribution rate of industrial structure adjustment for carbon emission reduction in various industries.

3. Analysis of the Contribution Rate of Industrial Structure Adjustment for Carbon Emission Reduction

3.1 Decomposition Model Setting

This paper uses a dynamic decomposition model to measure the contribution rate of industrial structure adjustment for carbon emission reduction, in order to distinguish two models, Q represents carbon emissions, p represents industrial added value, and q represents carbon emission intensity, represents the amount of carbon dioxide emissions brought by per unit GDP growth, α_0 and α_t, β_0 and β_t, γ_0 and γ_t represent the proportion of primary industry, secondary industry, and tertiary industry in GDP in the base year and t year, respectively. v_0 and v_t, w_0 and w_t, u_0 and u_t represent the carbon intensity of primary industry, secondary industry, and tertiary industry in the base year and t year, respectively; p_0 and p_t represent the GDP in the base year and t year, respectively; Q_0 and Q_t represents the corresponding carbon emissions.

The carbon emissions in t year can be calculated as follows:

$$\begin{aligned} Q_t &= p_t \times q_t \\ &= p_t \alpha_t V_t + p_t \beta_t W_t + p_t \gamma_t U_t \end{aligned} \tag{4}$$

The increment of carbon emissions can be expressed as follows:

$$\begin{aligned} \Delta Q &= Q_t - Q_0 \\ &= p_t(\alpha_0 + d\alpha)V_t + p_t(\beta_0 + d\beta)W_t + p_t(\gamma_0 + d\gamma)U_t - (p_0\alpha_0 V_0 + p_0\beta_0 W_0 + p_t\gamma_0 U_0) \end{aligned} \tag{5}$$

Therefore, the carbon emission reduction from the base year to t years:

$$\begin{aligned} \Delta Q^* &= -\Delta Q \\ \Delta Q_s &= p_t d\alpha V_t + p_t d\beta W_t + p_t d\gamma U_t \end{aligned} \tag{6}$$

ΔQ_s reveals the changes of carbon emissions caused by industrial structure adjustment.

$a_{t1} = \alpha_t$, $a_{t2} = \beta_t$, $a_{t3} = \gamma_t$, $q_{t1} = V_t$, $q_{t2} = W_t$, $q_{t3} = U_t$, the emission reduction from the base year to t year caused by industrial structure adjustment is calculated as follows:

$$\begin{aligned} \Delta Q^* &= -\Delta Q_s \\ &= -[p_t(\alpha_t - \alpha_0)V_t + p_t(\beta_t - \beta_t)W_t + p_t(\gamma_t - \gamma_0)U_t] \\ &= p_t \sum_{i=1}^{3}[q_{ti} \times (a_{0i} - a_{ti})] \end{aligned} \tag{7}$$

Therefore, the contribution rate of industrial structure adjustment for emission reduction can be expressed as follows:

$$C_s = \frac{\Delta Q_s^*}{\Delta Q^*} \times 100\% = \frac{-\Delta Q_s}{-\Delta Q} \times 100\%$$

$$= \frac{p_t \times \sum_{i=1}^{3}[q_{ti} \times (a_{0i} - a_{ti})]}{Q_0 - Q_t} \times 100\% \quad (8)$$

Similarly, the actual carbon emissions in t year can be calculated as follows:

$$Q_{1t} = p_{1t} \times q_t = \sum_{j=1}^{m}(p_{1t} \times a_{tj} \times q_{tj}) = p_{1t} \times \sum_{j=1}^{m}(a_{tj} \times q_{tj}) \quad (9)$$

In the above formula, p_{10} and p_{1t} are the total added value of the industrial sector in the base year and year t, respectively, a_{0j} and a_{tj} represent the ratio of the added value added in the j industry for the total added value in the corresponding two years respectively, and q_0 and q_t represent average carbon intensity in the base year and t year, respectively, q_{0j} and q_{tj}respectively represent the carbon emission intensity of industry j in the corresponding two years, respectively. J represents the industry sector.

The emission reduction is calculated as follows:

$$\Delta Q_1 = \Delta Q_{10} - \Delta Q_{1t} \quad (10)$$

It represents the emission reduction from the base year to t year, then, the emission reduction caused by the internal structure adjustment of the industrial sector from the base year to t year is calculated as follows:

$$\Delta Q_{1s} = p_{1t} \times \sum_{j=1}^{m}[(a_{0j} - a_{tj}) \times q_{tj}] \quad (11)$$

In summary, the contribution rate of industrial structure adjustment for emission reduction can be expressed as follows:

$$C_{1s} = \frac{\Delta Q_{1s}}{\Delta Q_1} \times 100\% = \frac{p_{1t} \times \sum_{j=1}^{m}[(a_{0j} - a_{tj}) \times q_{tj}]}{Q_{10} - Q_{1t}} \times 100\% \quad (12)$$

3.2 Analysis of Empirical Results

1. Contributions of industrial sector structural adjustment are different

When studying the carbon emission reduction effect of industrial structure adjustment, this paper focuses on the 11 representative industries in the secondary industry for specific research when each industrial sector is classified by added value.

Table 2. carbon emissions reductions caused by industrial structure adjustment in the main sectors of the secondary industry from 2006 to 2015 (unit: 10000 tons)

No.	industry	2006-2010	2011-2015
1	coal mining and cleaning mixture	-319.1	57
2	coal mining and washing industry	237	58.9
7	agricultural and sideline food manufacturing industry	-54.3	-6
11	textile industry	75.4	30.7
19	petroleum processing, coking and nuclear fuel manufacturing industries	28.6	23.8
20	chemical fuel and chemical manufacturing industry	-172.8	-328.2
21	pharmaceutical industry	1	-14.1
25	non-metallic mineral products industry	-631.8	-241.4
26	ferrous metal smelting and rolling manufacturing	308.6	-20.4
27	non-ferrous metal smelting and rolling processing industry	-102.9	-123
37	Electricity, heat production and supply industry	5675.7	4280.4

Note: The data in this table are based on empirical calculations.

The results show that it is more difficult to upgrade traditional industries, but at the same time, strategic emerging industries are developing rapidly, and the carbon emission reduction effects caused by industrial structure adjustment vary widely in industries, the effect of high pollution industry is the most obvious, such as electricity, heat production and supply industry, coal mining, petroleum processing and textiles industry. The power, heat production and supply industry are the industries with the largest carbon dioxide emissions in China, however, with the implementation of industrial upgrading and related policies on energy conservation and emission reduction, the slowing effect of carbon dioxide emissions caused by industrial structure adjustment will gradually weaken. On the other hand, increases of emissions from non-metallic mineral products, chemical fuel and chemical manufacturing, and pharmaceutical manufacturing industry will offset emissions reductions in other industries. According to the evolution of the industrial structure, the heavy chemical industry generally will not expand any more, even shrink in the later stages of industrialization, and the high-tech industries with low energy consumption and low emissions will gradually take advantage, this is also reflected in the continuous upgrading of China's industry.

2 Industrial Structure Adjustment has Positive Impact on Total Carbon Emission Reductions

The relevant parameters and emission reductions of the three industries are calculated according to the contribution rate, and the results are shown in the following table:

Table 3. contribution rate of industrial structure adjustment for carbon emission reduction from 2006 to 2015 (unit: 10000 tons)

	parameter	2006-2010	2011-2015
carbon emission reduction (unit: 10000 tons)	total emission reduction	-181816	-98802
	three major industrial structure adjustment	17285	27877
	agriculture	1805	376
	industry	23186	32609
	living consumption	-7688	-5107
	structure adjustment of secondary industry	4923	3726
contribution rate(%)	three major industrial structure adjustments	-9.51	-28.22
	structural adjustment of secondary industry	3.22	-4.26

Note: The data in this table are based on empirical calculations.

It can be found from the table above that despite the adoption of many low-carbon economic measures, the total carbon dioxide emissions of various sectors in China remained high during 2006-2015, but the absolute increase in carbon emissions declined, and the added value added of total emissions decreased from 188161 million tons in the first five years to 9882 million tons in the second phase, this is mainly because with the development of China's economy, on the one hand, the total demand for various energy and resources will increase, result in increase of total carbon emissions; on the other hand, it will also bring the improvement of technology and the replacement of green energy to mitigate and curb carbon emissions, the combination of the two makes China's current carbon emissions increase, but the growth rate gradually declines. It is foreseeable that with the further development of the economy and the continuous upgrading of the industry, it will bring about a labor-intensive to technology-intensive transition, increase of production efficiency, control of pollution sources, and further popularization of green energy.

4. Conclusion and Countermeasure Suggestions

Through the deformation of Kaya identity and LMDI decomposition model, this paper divides the influencing factors of carbon emissions growth into four factors (economic size, industrial structure, energy consumption intensity, and carbon emission coefficient), the calculation results show that: economic size is directly proportional to carbon emissions and has the greatest impact on carbon emissions; the energy consumption intensity and energy have a reverse effect on carbon emissions; the annual and periodical measurement results of the industrial structure from 2006 to

2015 shows that the industrial structure adjustment is positive and weak in reducing carbon emissions Impact.

Furthermore, the total carbon emissions are still large through dynamic decomposition models, but there is a downward trend year by year, the carbon emissions of secondary industry have ranked first; in carbon emission reduction, the carbon emission reductions brought about by the adjustment of the three major industrial structures are considerable, and they are gradually increasing and optimizing. We suggest that the proportion of clean energy should be increased, the energy consumption pattern should be optimized, the proportion of tertiary industry should be increased, the leading advantages should be exerted, the development of high-yield and low-emission industries should be emphasized, and transform and guide traditional industries towards green development.

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