Research on influencing factors and countermeasures of industrial carbon emission in Hebei province based on Kaya model

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Abstract. In view of the world carbon emission problem, the current status of low carbon economy research is reviewed. Based on the historical data of industrial carbon emissions in Hebei Province from 2008 to 2017, based on the historical data of industrial carbon emissions in Hebei Province, the Kaya decomposition model was used to find the industry affecting Hebei Province. The driving factors of carbon emission levels and the trends of various factors, and then combined with the LMDI model, the absolute contribution of each driving factor to the economic development of Hebei Province, and the specific analysis of carbon emission levels, and finally put forward rationalized emission reduction measures and suggest.

1. Introduction and literature review
As the global population and economic scale continue to accelerate, humans overuse fossil fuels, emit large amounts of greenhouse gases, and the world is facing warming. The issue of carbon emissions is receiving more and more attention from all countries.

Foreign countries have studied the issue of carbon emissions earlier. Soytas et al. (2007) study the dynamic relationship between economy, energy and carbon emissions in the United States from 1960 to 2004, and the analysis shows that there is a significant causal relationship between energy consumption and carbon dioxide emissions[1].Sandanayake et al. used process analysis to calculate the amount of greenhouse gas emitted by machinery in industrial production and manufacturing, and then calculated the proportion of each influencing factor by analytic hierarchy process[2].In recent years, Chinese scholars have paid more and more attention to the study of carbon emissions, and built many accounting models for carbon dioxide emissions. Dongmei Zhang, Ling Yang, Bo Li, etc. have established an indicator system for greenhouse gas emissions in Anhui Province, calculated 2001-2010. The amount of greenhouse gases emitted by various sectors in Anhui Province during the past decade, and finally propose targeted emission reduction policies based on the specific conditions of Anhui Province[3].Dan Tan et al. calculated the total carbon emission of China's three major regions (east, middle and west) and analyzed the differences of carbon emission in these three regions. On this basis, the relative correlation degree of carbon emission and gross product of the three regions was calculated by using the grey correlation method, and the measures to reduce China's carbon emission were proposed [4].

According to the above can be seen that the existing research mainly concentrated in the construction of carbon dioxide emissions from various angles calculation model for carbon emissions accounting, and both from national macro level, to a particular regions and provinces industrial analysis of the
influence factors of carbon emissions is less, so, this article takes Hebei province as an example, study in Hebei province industrial carbon emissions problem, in this paper, based on the improved carbon Kaya decomposition model, in 2008, for the base period, from 2008 to 2017 in Hebei province to study the situation of carbon emissions, the conclusion of several major driving factors of industrial carbon emissions in Hebei province In order to provide solutions for the economic and social development of Hebei province.

2. Model building

2.1. Kaya prediction model
At present, there are still many shortcomings in the research on the factors affecting carbon emissions, but some of the more mature theories are also accepted by the public. The most accepted one is the Japanese scholar Yochi Kaya in 1989 at the UN Intergovernmental Panel on Climate Change (IPCC). The seminar held at the seminar proposed the CO\(_2\) identity, also known as Kaya's identity equation[5]. In the current model for quantitative analysis of carbon emissions, it is widely used to explain an identity of the relationship between carbon emissions and population size and economic growth[6], which can be expressed as follows:

\[
CO_2 = P \cdot \frac{GDP}{P} \cdot \frac{E}{GDP} \cdot \frac{CO_2}{E}
\]  

(1)

2.2. Kaya decomposition model of factors affecting industrial carbon emissions
This paper aims to analyze the factors affecting industrial carbon emissions in Hebei Province. Only considering the above factors is not comprehensive. Therefore, based on the Kaya theory, the Kaya identities are improved, and the energy structure effects and other influencing factors are added. The improved industrial industry Kaya decomposition Model Hebei Province Total Industrial Carbon Emissions.

\[
MC = \sum MC_i = \sum \frac{MC_i}{E_i} \times \frac{E_i}{NH} \times \frac{NH}{GDP} \times \frac{GDP'}{P'} \times P'
\]  

(2)

The energy emission intensity factor \(F_i = MC_i/E_i\) can be defined by formula (2), that is, the carbon emission generated by the i-th energy source of the consumption unit; the energy structure factor \(S_i = E_i/NH\), the share of the i-th energy in the total primary energy consumption; energy efficiency factor \(I = NH/GDP'\), that is, the energy consumption per unit of industrial output; industry economic development factors \(R = GDP'/P'\), the per capital GDP of the industrial sector; in addition, the change in the t-phase of the industrial industry relative to the carbon emissions in the base period

\[
\Delta MC = MC' - MC^0
\]  

(3)

The simplified Kaya model is

\[
MC = \sum MC_i = \sum F_iS_iIRP'
\]  

(4)

Based on equations (2)-(4), combined with the IMDI analysis method, the contribution degree of each driving factor is decomposed and calculated, and the contribution value of carbon emission variation of each influencing factor is:

\[
\Delta MC_S = \sum \frac{3}{i=1} W_i' \ln \frac{S_i'}{S_i^0};
\]

\[
\Delta MC_I = \sum \frac{3}{i=1} W_i' \ln \frac{I'}{I^0};
\]

\[
\Delta MC_F = \sum \frac{3}{i=1} W_i' \ln \frac{F_i'}{F_i^0};
\]
\[
\Delta MC_R = \sum_{i=1}^{3} W'_i \ln \left( \frac{R'_i}{R^0} \right);
\]
\[
\Delta MC_P = \sum_{i=1}^{3} W'_i \ln \left( \frac{P'_i}{P^0} \right);
\]

Among them,
\[
W'_i = \frac{MC'_i - MC^0_i}{\ln(MC'_i / MC^0_i)} \tag{5}
\]

3. Decomposition of factors affecting industrial carbon emissions in Hebei Province

3.1. Data sources and organization

In the raw data used in this study, the total carbon emissions of industrial industries were obtained by reference to the industrial greenhouse gas estimation method in the “Guidelines for the Compilation of Provinical Greenhouse Gas Inventories”. The energy of industrial industries in Hebei Province was obtained from the “China Energy Statistics Year Book” over the years. For consumption, refer to the relevant data of Hebei Statistical Year book. The collected raw data are shown in Table 1 and Table 2.

| Energy type          | Raw coal       | Electric-power \times10^4/t\cdot(\text{KWh})^{-1} | Gasoline | Diesel | Thermal-energy \times10^6/t\cdotkJ^{-1} |
|----------------------|----------------|-----------------------------------------------|---------|-------|--------------------------------------|
| Folding factor       | 0.7143         | 1.229                                         | 1.4714  | 1.4571| 0.03412                              |
| Carbon emission coefficient | 1.9003   | 12.46                                         | 2.9251  | 3.0959| 0.0839                              |

Table 2. Historical data of industrial industry in Hebei Province from 2008 to 2017

| years | Industrial output \times10^4/t | Industrial production value / 10,000 yuan | Number of employed people / person | Total energy consumption standard/ tce | Total electricity consumption \times10^4/kWh | Power consumption discount/ tce | Other energy consumption discount amount/tce |
|-------|-------------------------------|------------------------------------------|-----------------------------------|-----------------------------------|---------------------------------|---------------------------------|---------------------------------------------|
| 2008  | 13087                         | 5663638                                  | 259739                            | 1156387                           | 510672                         | 627616                         | 528771                                      |
| 2009  | 13788                         | 5866801                                  | 259440                            | 1148560                           | 374213                         | 459907                         | 688653                                      |
| 2010  | 13681                         | 5920745                                  | 286012                            | 1045290                           | 364894                         | 488454                         | 596836                                      |
| 2011  | 13491                         | 5838259                                  | 239050                            | 970017                            | 393673                         | 483824                         | 486193                                      |
| 2012  | 14050                         | 6080086                                  | 267899                            | 945566                            | 408434                         | 501965                         | 443601                                      |
| 2013  | 14892                         | 6444484                                  | 282094                            | 942669                            | 426360                         | 523997                         | 416872                                      |
| 2014  | 15345                         | 6640760                                  | 327830                            | 928411                            | 381799                         | 469232                         | 459180                                      |
| 2015  | 14500                         | 6275129                                  | 347974                            | 813491                            | 346712                         | 429110                         | 387381                                      |
| 2016  | 15152                         | 6557318                                  | 334639                            | 868257                            | 381699                         | 469109                         | 399148                                      |
| 2017  | 14804                         | 6406692                                  | 301626                            | 840910                            | 373376                         | 458879                         | 382031                                      |
3.2. Analysis of factors affecting carbon emissions

According to the relevant data of formula (1) and Table 1, Table 2, the carbon emission levels (including per capital carbon emission levels) of the industrial industry in Hebei Province are shown in Figure 1.

![Fig.1 2008-2017 Annual Industrial Carbon Emissions in Hebei Province (Unit: 10^7)](#)

It can be found from Figure 1 that the total carbon emissions of industrial industries and the per capital carbon emission levels are generally consistent, which indicates that the current economic development of industrial industries is mainly driven by energy consumption, accompanied by a large amount of energy consumption, a large number of carbon emissions are inevitable.

The trend of each driving factor is obtained from the relevant data in equations (1), (2) and Tables 1 and 2, as shown in Fig.2.

![Fig.2 Trends in drivers from 2008 to 2017](#)

It can be seen from the trend of Figure 2 that the trend of various driving factors has been uneven in the past 10 years. Among them, the energy efficiency effect has been generally showing an upward trend; the trend of industrial economic effects and population size effects has risen and fallen. Since the carbon emission coefficient of primary energy does not change, the intensity of energy emission has been tending to be stable. Compared with the change in total carbon emissions, it is known that this driving factor does not have a greater impact on the total amount of carbon emissions; The structural effect reflects the impact of the size of the primary energy consumption structure in the industrial sector on carbon emissions.

After analyzing the trends of various driving factors, the data of formula (3), formula (4), Formula (5) and Tables 1 and 2 are used to obtain the absolute contribution of each driving factor to the carbon emissions of industrial industries. As shown in Figure 3.
Fig. 3 Contributions of various driving factors to total industrial carbon emissions, 2008-2017

4. Conclusion and recommendations

4.1. Conclusion
As can be seen from the above chart, the contribution value of energy emission intensity to industrial carbon emission is 0, so energy emission intensity is irrelevant. The contribution value of the energy structure effect is always positive and shows an increasing trend year by year. Therefore, it can be seen that the energy structure effect is the driving factor. The absolute contribution value of energy efficiency effect is always negative, and the negative contribution value increases year by year, which is the inhibiting factor. The first half of the contribution value of industrial economic effect to the total carbon emission is positive. However, with the improvement of industrial technology and the transformation of economic development mode, it starts to make a negative contribution to the total carbon emission. If the technological research and development continues in the future, industrial economic effect will become a restraining factor. In addition, due to the positive correlation of population size effect on the coal industry, this factor can be judged as a driving factor.

4.2. Carbon emission reduction and recommendations
(1) Promote the low carbonization of traditional high carbon industries. We must increase efforts to eliminate backward production capacity and technical equipment in some high-carbon industries in Hebei Province. Promote industrial industries to improve production technology, optimize technical equipment, improve energy efficiency in the industrial sector, and actively develop cogeneration.
(2) Adjust the energy structure and build a low-carbon energy system. Optimize energy structure, develop renewable resources, vigorously support the development and use of zero-carbon and low-carbon energy, and continuously improve the utilization of natural gas and renewable resources.
(3) Innovative carbon reduction technology. Among the influencing factors, the energy intensity of output is also an important factor. The governance of carbon emissions in industrial industries in Hebei Province depends on the improvement of energy efficiency. Increase investment in low-carbon technology and improve industrial technology.

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