Empirical Analysis of Environmental Constraints and Influencing Factors in Beijing-Tianjin-Hebei Region

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Abstract. This paper focuses on carbon emissions problem and adopts the "bottom-up" method proposed by IPCC to calculate the energy consumption carbon emission of leading industries in the Beijing-Tianjin-Hebei region. And constructed the Tapio decoupling index model to analyze the "decoupling relationship" between the development of leading industries and energy consumption and carbon emissions in various regions, so as to quantify the environmental constraint levels of different industrial development. Finally, this paper uses LMDI model to decompose the carbon emission factors, and explores the environmental impact of industrial leading industries in Beijing-Tianjin-Hebei region from the four dimensions of carbon emission intensity, energy intensity, economic development and population size, in order to effectively promote the optimization of industrial structure in Beijing-Tianjin-Hebei region and to achieve pareto optimization.

1. Introduction
In the 21st century, the integration of Beijing, Tianjin and Hebei has begun to speed up, but the acceleration of the integration process has not significantly improved people's quality of life. Beijing-Tianjin-Hebei region has become the region with the most serious air and water pollution and the most water resources shortage, as well as the area with the most contradiction between resources and industrial development [1]. Unfortunately, although the economic links between the three regions are relatively close, there is no consensus on environmental issues. The three regions are independent, so the pace of environmental improvement is inconsistent, and the cooperation capacity among the three regions is not complementary, the information between regions is not transparent, and the regional resources are not optimized. The above problems are unfavorable factors restricting the integration of Beijing, Tianjin and Hebei. Therefore, it is urgent to scientifically assess the environmental risk in Beijing, Tianjin and Hebei, and find out the optimal industrial layout suitable for the development of the three regions. Therefore, it is urgent to carry out scientific assessment of the environmental risk of the region and find out the optimal industrial layout suitable for the development of the three regions.

2. Literature review
With the rapid development of China's industry, research on the impact of environmental regulation on industrial layout is increasing. Zhou concluded that environmental regulations had a great impact on
the production layout of pig industry from 2004 to 2015 by analyzing the panel data of inter-provincial pig breeding in China. They proposed that different regions should formulate different environmental regulation standards and regulatory policies, so as to achieve a win-win situation of environment and economic benefits [2]. Wang establishes a decoupling index system and analyzes the relationship between economic growth and environmental pressure in Beijing-Tianjin-Hebei region[3]. Mastering the influencing factors of carbon emission is very important for reducing carbon emission. Based on LMDI model, the influencing factors of carbon emissions in various industries can be decomposed [4-6]. For example, the influencing factors of carbon emissions in metallurgical industry include labor productivity, energy intensity and industrial scale [7]. The influencing factors of carbon emissions increase in transportation industry are population growth and increase of all vehicles [8]. The research on the composition of the influencing factors of carbon emission in different industries provides a theoretical basis for the industrial layout. Wang analyzed the impact of carbon emission tax on the optimal production decision of manufacturing and remanufacturing. The research shows that under the carbon emission tax policy, there are reasonable remanufacturing production strategies based on cost saving and carbon emission reduction of different remanufactured products [9]. Economic development, population growth and other factors will lead to the increase of energy consumption, which will lead to the increase of carbon emissions [10, 11]. In order to grasp the relationship between economic development and carbon emission, scholars have turned their attention to decoupling phenomenon. Decoupling phenomenon of carbon emissions can effectively reveal the main influencing factors and mechanisms of carbon emissions change and provide a theoretical basis for the government to formulate emission reduction strategy and industrial development layout [12, 13].

Wang used the generalized divisor index (GDIM) to analyze the driving factors of carbon emission in China's transportation industry from 2000 to 2015, estimated the decoupling elasticity between the development of China's transportation industry and carbon emission, and put forward the policy suggestions for carbon emission reduction in transportation industry based on the analysis results [14]. Zhou used quantitative analysis method to study the decoupling relationship between carbon emissions and economic growth in eight regions of China from 1996 to 2012. The logarithm average factor index (LMDI) was used to decompose the main factors affecting the change of carbon emission in various region. The conclusion shows that the overall level of carbon emission reduction technology in China is low and backward, and its contribution to economic growth and industrial energy is limited. The future development should focus on the promotion of energy-saving technology, the upgrading of industrial structure and the improvement of energy structure [15].

In summary, scholars from all over the world have fully confirmed the influencing factors of carbon emissions, and the research on the decomposition and decoupling of the influencing factors between economic development and carbon emissions has laid a solid foundation. However, the existing research has the following shortcomings: 1. Lack of research on the impact of environmental pressure caused by industrial carbon emissions on regional industrial layout planning. 2. Lack of research on the optimization of the overall industrial structure between regions. Based on the current situation of the existing research, under the background of the integrated development of Beijing-Tianjin-Hebei region, this paper analyzes the current situation of the industrial layout of Beijing-Tianjin-Hebei region with the economic and environmental factors as the focus of the optimization of the industrial layout.

3. Research method and data sources

3.1. Current Situation of Leading Industrial Structure in Beijing-Tianjin-Hebei Region

Beijing, Tianjin and Hebei region have significant differences in location quotient, and the leading industries of the three regions are different. The calculation of location quotient only from the perspective of the first, second and third industries has limitations in studying the leading industry of the region, and it is more meaningful to study the leading industry from a more detailed level. From the perspective of the impact on the environment and the constraint of environmental resources,
compared with the primary and tertiary industries, the secondary industry shows a higher correlation with the environment. Therefore, this section focuses on the study of industries in the secondary industry.

3.2. Data sources
To further clarify and refine the leading industries in Beijing, Tianjin and Hebei, this paper calculates the industry location quotient based on the data of Beijing Statistical Yearbook, Tianjin Statistical Yearbook, Hebei Statistical Yearbook and China Statistical Yearbook. In this paper, taking Beijing Statistical Yearbook, Tianjin Statistical Yearbook, Hebei Statistical Yearbook and China Statistical Yearbook from 2008 to 2017 as data sources, this paper excludes the industries with missing data and estimates the location quotients of 39 sub-industries in industry. In order to get a clearer understanding of the situation of the leading industries in the three regions, the overlap tables of the leading industries in the three regions (see Table 1) are sorted out according to the principle that the location quotient is greater than 1.

| Region              | Coincidence Industry                                                                 |
|---------------------|--------------------------------------------------------------------------------------|
| Beijing and Tianjin | Mining ancillary activities; Food manufacturing industry; Automobile manufacturing industry; Railway, ship, aerospace and other transport equipment manufacturing industry; Other manufacturing industries; Metal products, machinery and equipment repair industry; Water production and supply industry. |
| Beijing and Hebei   | Food manufacturing industry; Electricity, thermal production and supply industry.     |
| Tianjin and Hebei   | Food manufacturing industry; Petroleum processing, coking and nuclear fuel processing industry; Ferrous metal smelting and calendaring industry; Metal products industry. |
| Beijing, Tianjin and Hebei | Food manufacturing industry.                                                   |

As can be seen from the table 1 and table 2, there are 12 leading industries in Beijing, 15 leading industries in Tianjin and 10 leading industries in Hebei. There are seven overlapping industries in Beijing and Tianjin, two in Beijing and Hebei, four in Tianjin and Hebei, and one in Beijing, Tianjin and Hebei. Therefore, industrial transfer can be carried out among Beijing, Tianjin and Hebei, so as to promote the optimization of industrial layout and realize the healthy development of regional economic integration.

4. Calculation and discussion

4.1. Estimation of Carbon Emission in Beijing-Tianjin-Hebei Region

4.1.1. Data sources. In order to better analyze the environmental conditions of the leading industries in Beijing, Tianjin and Hebei, and to account the availability and rationality of data, data collection is carried out according to the leading industries in Beijing, Tianjin and Hebei. Two industries with incomplete historical data were excluded from Beijing and Tianjin respectively. The data are from the China Energy Statistics Yearbook, Beijing Statistics Yearbook, Tianjin Statistics Yearbook and Hebei Statistics Yearbook in 2017.

4.1.2. Carbon emission measurement method. China's official agencies do not publish carbon emissions data for all provinces and industries, so carbon emissions data need to be calculated. This paper uses the "bottom-up" method proposed by IPCC to calculate the total carbon emissions by
estimating and summing up the various energy consumption in the industry [16]. The carbon emissions mentioned in this paper refer to CO2 emissions. The specific calculation formula is as shown in (1):

\[
CO_2 = \sum_{i=1}^{n} CO_{2i} = \sum_{i=1}^{n} E_i \times CF_i \times COF_i \times \frac{44}{12} = \frac{44}{12} \sum_{i=1}^{n} \alpha_i E_i
\]  

(1)

Where, \( CO_2 \) represents the total amount of carbon emissions from energy consumption. \( i \) represents the type of energy, \( i = 1, 2, ..., n \). \( E_i \) represents the energy consumption of type \( i \). \( CF_i \) represents the conversion factor of the \( ith \) energy source, also known as the average low calorific value. \( CC_i \) represents the carbon content of the \( ith \) energy source. \( COF_i \) represents the oxidation factor of the \( ith \) energy source, reflecting the oxidation rate level. 44/12 is the conversion factor from \( C \) to \( CO_2 \). \( \alpha_i \) represents the carbon emission coefficient of the \( ith \) energy. Data are all from established IPCC coefficients (see Table 2).

Table 2. Carbon Emission Coefficient of Various Energy Sources

| Energy Types       | Coal | Diesel | Gasoline | Natural Gas | Fuel Oil | Liquefied Petroleum Gas |
|--------------------|------|--------|----------|-------------|----------|-------------------------|
| Carbon Emission Coefficient (Tons of Carbon/Tons of Standard Coal) | 0 . 7599 | 0 . 5921 | 0 . 5538 | 0 . 4483 | 0 . 6815 | 0.5042 |

Data Source: Data collation based on IPCC Guidelines for Carbon Emission Computation

4.2. Decomposition Analysis of Influencing Factors of Carbon Emission

In order to grasp the influencing factors of carbon emission in the Beijing-Tianjin-Hebei region as a whole, this paper took the Beijing-Tianjin-Hebei region as a whole to conduct a study, used Kaya identity and LMDI model to decompose the influencing factors of carbon emission in the Beijing-Tianjin-Hebei region, and analyzed the contribution of various influencing factors to the carbon emission in the Beijing-Tianjin-Hebei region from 2007 to 2016.

4.2.1. Decomposition of carbon emission factor in LMDI model. Yoichi Kaya, a Japanese scholar, proposed Kaya identity to study the factors affecting carbon emissions from energy consumption. The equation is to decompose the total carbon emissions into the product of several factors, and then quantitatively analyze the total carbon emissions and energy consumption, economy and population. The specific formula is as follows:

\[
CO_2 = \frac{CO_2}{E} \times \frac{E}{GDP} \times \frac{GDP}{POP} \times POP
\]  

(2)

Among them, \( CO_2 \) represents carbon emissions from energy consumption, \( E \) represents total energy consumption, \( GDP \) represents economic output, and \( POP \) represents population. \( CO_2 / E, E / GDP \) and \( GDP / POP \) represent carbon emission intensity, energy intensity and per capita \( GDP \) [17]. For convenience, the above formula is changed into:

\[
\Delta C = C^t - C^0 = \Delta C_E + \Delta C_I + \Delta C_Y + \Delta C_P
\]  

(3)

According to the core idea of LMDI factor decomposition model, formula 4 can be decomposed without residual, and formula 5 can be obtained:

\[
C = E \times I \times Y \times P
\]  

(4)

Where, \( \Delta C \) represents the change of carbon emission of energy consumption from the base period to the \( t \) period. \( C^t \) represents the carbon emission of energy consumption in the \( t \) period. \( C^0 \) represents the carbon emission of energy consumption in the base period. \( \Delta C_E, \Delta C_I, \Delta C_Y, \Delta C_P \) respectively represent the carbon emission intensity effect, energy intensity effect, economic
development effect and population size effect.

\[
\Delta C_E = \frac{C_t - C_0}{\ln C_t - \ln C_0} \times \ln \frac{E_t}{E_0}
\]

(5)

\[
\Delta C_I = \frac{C_t - C_0}{\ln C_t - \ln C_0} \times \ln \frac{I_t}{I_0}
\]

(6)

\[
\Delta C_Y = \frac{C_t - C_0}{\ln C_t - \ln C_0} \times \ln \frac{Y_t}{Y_0}
\]

(7)

\[
\Delta C_P = \frac{C_t - C_0}{\ln C_t - \ln C_0} \times \ln \frac{P_t}{P_0}
\]

(8)

If the calculated contribution value is greater than 0, it indicates that this factor has a positive effect on the growth of carbon emissions in Beijing, Tianjin and Hebei, which will increase carbon emissions. If the calculated contribution value is less than 0, it indicates that this factor has a negative effect on the increase of carbon emissions in Beijing, Tianjin and Hebei region, and will reduce carbon emissions.

4.2.2. Results and discussion. This research year is 2007-2016. The data mainly come from China Energy Statistics Yearbook, Beijing Statistics Yearbook, Tianjin Statistics Yearbook and Hebei Statistics Yearbook. Take 2006 as the base period, according to formula 6, formula 7, formula 8 and formula 9, calculate and sort out Table 3. Among the factors that affect carbon emissions, those that increase carbon emissions are classified as negative driving effects, while the increase of carbon emissions is classified as positive driving effects. According to the trend and contribution rate, carbon emission intensity effect and energy intensity effect are negative driving effects, while economic development effect and population scale effect are positive driving effects.

As can be seen from table 3, from the perspective of contribution rate, economic development effect has the largest positive contribution to carbon emissions, with the highest contribution rate of 2.52%, and energy intensity effect has the largest negative contribution to carbon emissions, with the lowest contribution rate of -1.83%. It shows that the decrease of carbon emission mainly comes from the decrease of energy consumption per unit of GDP, while the increase of carbon emission mainly comes from the increase of per capita GDP. In 2016, the carbon emissions in Beijing-Tianjin-Hebei region increased by 181.7 million tons compared with the base period. Among them, the contribution of carbon emission intensity effect was - 44.047 million tons, the contribution of energy intensity effect was - 31.91 million tons, the contribution of economic development effect was 42.817 million tons, and the contribution of population scale effect was 116.85 million tons. In 2008 and 2014, the carbon emission of the Beijing, Tianjin and Hebei region was lower than that of the previous year. Especially in 2014, the carbon emissions decreased significantly, and then showed a downward trend in the following years. In other years, carbon emissions are increasing, mainly because the negative contribution of carbon emission intensity effect and energy intensity effect to carbon emissions is greater than the positive contribution of economic development effect and population size effect, indicating that carbon emissions have gradually decreased in recent years, and environmental pressure has gradually eased.

As can be seen from Figure 1, the contribution value of carbon emission intensity effect in 2008, 2014, 2015 and 2016 is negative, and the overall trend of contribution value is declining. The contribution value of energy intensity effect is always negative, and the negative effect increases year by year. The effects of economic development and population size were positive during the study period, and the contribution of the effects showed an upward trend in general. The trend of total effect is in the same direction with the intensity effect of carbon emission. The lower the contribution of carbon emission effect is, the lower the total effect.
| Year | Carbon emission intensity effect | Energy intensity effect | Economic development effect | Population scale effect | Total effect |
|------|---------------------------------|------------------------|----------------------------|-------------------------|--------------|
|      | Contribution value | Contribution rate | Contribution value | Contribution rate | Contribution value | Contribution rate |                       |                        |              |              |
| 2007 | 2043.44             | 0.28                  | -6031.18                | -0.83                  | 10097.25        | 1.39             | 1142.29                 | 0.16                  | 7251.8       |
| 2008 | -365.49             | -0.05                 | -12683                  | -1.83                  | 17480.43        | 2.52             | 2515.24                 | 0.36                  | 56947.1      |
| 2009 | 769.45              | 0.07                  | -14675.5                | -1.24                  | 21728.6         | 1.84             | 4007.22                 | 0.34                  | 11829.5      |
| 2010 | 2188.48             | 0.13                  | -21193.9                | -1.3                   | 28652.22        | 1.76             | 6601.38                 | 0.41                  | 16248.7      |
| 2011 | 3872.5              | 0.16                  | -26360.4                | -1.11                  | 37737.9         | 1.6              | 8400.7                  | 0.36                  | 23650.2      |
| 2012 | 3196.62             | 0.12                  | -28537.5                | -1.11                  | 41236.55        | 1.61             | 9743.85                 | 0.38                  | 25639.0      |
| 2013 | 2090.56             | 0.08                  | -30376.9                | -1.16                  | 43565.44        | 1.67             | 10876.36                | 0.42                  | 482615.5    |
| 2014 | -1301.82            | -0.06                 | -30605.1                | -1.42                  | 42260.56        | 1.96             | 11187.38                | 0.52                  | 201541.3    |
| 2015 | -2348.42            | -0.12                 | -30943.8                | -1.54                  | 41869.53        | 2.08             | 11578.64                | 0.57                  | 20155.9      |
| 2016 | -4404.7             | -0.24                 | -31912                  | -1.76                  | 42801.7         | 2.36             | 11685                   | 0.64                  | 18170        |

Table 3. Factors and degrees of carbon emission effect in Beijing-Tianjin-Hebei region from 2007 to 2016.
5. Conclusion

In this paper, Tapio decoupling index model is constructed to quantify the environmental constraint level of industrial development, and LMDI model is used to decompose carbon emission factors to analyze the environmental impact of three leading industries in Beijing, Tianjin and Hebei. Scientifically evaluate the industrial development and environmental risks in Beijing Tianjin Hebei region, and explore the optimization of industrial structure in Beijing Tianjin Hebei region. The main conclusions of this study are as follows:

1. According to the analysis of the carbon emissions of Beijing, Tianjin and Hebei. Hebei province has the largest carbon emissions among the three regions, but the total carbon emissions of the three regions show a zigzag downward trend, and the trend of change is most obvious in Tianjin. The data shows that the overall trend of carbon emissions in Beijing-Tianjin-Hebei region shows a positive development, but the total carbon emissions are still very large, and in a fluctuating change, which brings great pressure on the environment.

2. The carbon emission intensity effect and energy intensity effect in Beijing, Tianjin and Hebei are negative driving effects, while the economic development effect and population scale effect are positive driving effects. The reduction of carbon emission mainly comes from the reduction of energy consumption per unit of GDP. And the carbon emission in Beijing, Tianjin and Hebei has been gradually reduced, and the environmental pressure has been gradually relieved.

In conclusion, this paper analyzes the factors affecting carbon emissions in Beijing, Tianjin and Hebei, and concludes that carbon intensity, energy intensity, economic development and population growth have different degrees of impact on carbon emissions. In order to realize the green, healthy and low-carbon economic development of Beijing, Tianjin and Hebei, it is necessary to strengthen the use of clean energy, improve the energy utilization rate, control the natural population growth in the region, and keep the pace of economic development and environmental protection.

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