Beijing-Tianjin-Hebei scenario design and model research under the constraint of emission peak

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Abstract. Beijing-Tianjin-Hebei cooperation and taking the lead in the peak of carbon emissions is an important research direction of Beijing-Tianjin-Hebei collaborative development. According to the social development and coordination degree of Beijing-Tianjin-Hebei, three scenarios of low, medium and high modes were set up, as well as a variety of combinations, based on the extended STIRPAT model, predicting carbon emissions peak, and choose the best development mode. On this basis, to explore factors impacts on peak value and peak time. The results show that: The optimal development pattern and peak time of Beijing-Tianjin-Hebei under peak-emission constraints are similar. Beijing should develop high-low mode in the future under carbon peak constraint, Tianjin and Hebei choose high-low + industrial optimization model. The peak times of Beijing, Tianjin and Hebei are 2025; Population is the main influencing factor to promote the peak time and the peak-value decrease of Beijing-Tianjin-Hebei, while the rapid economic development is the main influencing factor of peak time delay and increasing peak value; Therefore, the coordinated development of Beijing-Tianjin-Hebei future on the basis of guarantee the quality of economic development, it should be the main control of the total urban population, rational control of economic growth, optimize the adjustment of industrial structure.

Key words. Emission peak; STIRPAT model; Scenario analysis; Collaborative development; Influence factor

1. Introduction
Global warming is a matter of concern to the world. The International Energy Agency has shown that: In 2013, the world’s carbon emissions from human activities reached 36 billion tons, and China accounted for 29% of the largest total volume. In the “United States Joint Statement on Climate Change”, China promised Carbon emissions peak around 2030. The rapid development of the eastern coastal areas is the first to explore ways and means to reach the peak of emissions, which can not only reserve space for the development of the central and western regions, but also form a good demonstration effect for the central and western regions, and thus promote the country’s carbon emissions to reach peaks as soon as possible. The Beijing-Tianjin-Hebei region is one of the regions
with rapid economic development, large population size, dense urban agglomerations and industrial clusters in the eastern part of the country, and is a region with relatively concentrated carbon emissions. Therefore, the Beijing-Tianjin-Hebei region is the top priority for energy conservation and emission reduction in China. It is a good example to reach the first peak of carbon. The “carbon emission peak” of Beijing-Tianjin-Hebei has a direct impact on the speed and quality of China’s emission reduction targets. In recent years, the coordinated development of Beijing, Tianjin, and Hebei has become a new model and trend of Beijing-Tianjin-Hebei development. Therefore, Beijing-Tianjin-Hebei cooperation and the early arrival of carbon peaks have become a research hotspot.

Second, the model method and data source

2. Model method and data source

2.1. STIRPAT Model.
The model is Dietz T’s limitation for overcoming proportional changes, and the equations were established as stochastic models. Through the statistical regression of population, wealth, and technical conditions, a random estimate of the impact of carbon emissions will be made. The model is expressed as:

\[ I = aP^b A^c T^d e \]  

In the formula (1): \( I, P, A, T \) Respectively indicate environmental pressure, population size, affluence and technical level; \( a \) is the coefficient of the model; \( b, c, d \) respective variable index; \( e \) is model error.

2.2. STIRPAT Model extension.
Based on the research of many scholars, starting from different scenarios of population, economic development, technological level, and industrial structure, and combining the characteristics of Beijing, Tianjin, and Hebei, choose the population (million people) and per capita (million/million people), The carbon emission intensity (t/million) and the proportion of the secondary industry (%) are four factors that have been STIRPAT extended to the model:

\[ I = aP^b A^c T^d I_s f \]  

Convert to log-linear model:

\[ \ln I = \ln a + b \ln P + c \ln A + d \ln T + e \ln I_s + \ln f \]  

Among them, \( I \) is Carbon emissions, \( P \) is population, \( A \) is per capita GDP, carbon emission intensity, \( a \) is are model coefficients (constant terms), \( b, c, d, e \) in turn represent the elasticity coefficient of each variable, \( f \) is a random error term.

In related studies, the relationship between economic development and carbon emissions is not a simple linear relationship. According to the Kuznets Curve Theory, there may be a quadratic or N-fold curve between per capita GDP and carbon emissions, so consider the per capita GDP becomes a quadratic relationship and the revised equation is:
\[ \ln I = \ln a + b \ln P + c \ln A + d(\ln A)^2 + e \ln T + f \ln I_s + \ln h \]  

(4)

2.3. Data Sources

This paper selects the data of Beijing-Tianjin-Hebei from 2002 to 2016 as the research sample, and the data from each province and city come from the statistical yearbooks of each province. The energy consumption carbon emissions data calculated in this paper is based on the apparent energy consumption accounting method given in the “2006 National Greenhouse Gas Inventories Guide” prepared by the IPCC. The carbon emissions are equal to the coal consumption and corresponding emissions of various energy consumption standards. The product of coefficient and status calorific value. In order to ensure the reliability and accuracy of accounting, the low calorific value and emission coefficient of various fossil energy sources should adopt data suitable for China's national conditions as much as possible, and the “carbon emission coefficient” recommended by the Energy Research Institute of the National Development and Reform Commission is 1.67 KG. The standard carbon's low calorific value is 29270KJ.

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2.4. Beijing-Tianjin-Hebei carbon emission model

In order to overcome the effect of multicollinearity, Ridge Regression was chosen to fit the model and the variance of the parameter estimator was reduced at the expense of bias.

| Variable | Beijin | Tianjin | Hebei |
|----------|--------|---------|-------|
| lnP      | 0.167  | 1.014   | 5.517 |
| lnA      | 0.120  | 0.025   | 0.152 |
| (lnA)^2  | 0.005  | 3.127   | 10.598|
| lnT      | -0.043 | -0.377  | -0.089|
| lnIs     | -0.189 | -0.037  | 1.970 |
| Constant | 5.928  | 2.941   | -4.264|

Table 1. Beijing-Tianjin-Hebei Ridge Regression Coefficient and Estimated Results

Note: B is the coefficient. *** indicates significant at the 0.01 level, ** indicates significant at the 0.05 level, and * indicates significant at the 0.1 level.

Therefore, the Beijing-Tianjin-Hebei model based on the ridge regression method is:

\[ \ln I = 0.167 \ln P + 0.120 \ln A + 0.005(\ln A)^2 - 0.043 \ln T - 0.189 \ln Is + 5.928 \]

(5)

\[ \ln I = 1.014 \ln P + 0.025 \ln A + 0.002(\ln A)^2 - 0.377 \ln T + 0.037 \ln Is + 1.706 \]

(6)

\[ \ln I = 1.589 \ln P + 0.152 \ln A + 0.007(\ln A)^2 - 0.089 \ln T + 1.970 \ln Is - 4.264 \]

(7)

2.5. Scenario parameter design

Three rates of change (2015-2035) are set based on factors such as population, per capita GDP, carbon intensity, and proportion of the secondary industry: low, medium, and high models. Taking the social development situation of the Beijing-Tianjin-Hebei not taking energy saving and emission reduction policies and measures as a benchmark, it is a low model. According to the “13th Five-Year Plan”
energy structure, industrial structure and energy-saving technologies and other coordinated development policy set as the mode. Based on this model, the accelerated development rate is set to high.

Table 2. Parameters Design of Beijing-Tianjin-Hebei Development Scenario 2015-2035

| Mode   | variable | 2016-2020 | 2021-2025 | 2025-2030 | 2030-2035 |
|--------|----------|-----------|-----------|-----------|-----------|
|        | Beijing  | Tianjin   | Hebei     | Beijing   | Tianjin   | Hebei     | Beijing   | Tianjin   | Hebei     |
| Low    | P (%)    | 1.38      | 2.0       | 0.6       | 0.0       | 0.1       | 0.3       | -2.0      | -0.1      | 0.1       | -4.0      | -0.5      | 0.0       |
|        | A (%)    | 3.0       | 6.0       | 6.0       | 3.0       | 4.5       | 5.0       | 2.0       | 3.0       | 4.0       | 2.0       | 2.0       | 3.0       |
|        | T (%)    | -4.0      | -5.0      | -5.0      | -3.0      | -3.0      | -4.5      | -2.0      | -2.0      | -5.0      | -2.0      | -1.0      | -4.0      |
|        | Is (%)   | 1.0       | 0.5       | 0.65      | -1.0      | 0.0       | 0.0       | -3.0      | -0.5      | -0.1      | -4.0      | -0.5      | -0.5      | -2.0      |
| Mid    | A (%)    | 5.0       | 7.0       | 7.0       | 4.0       | 5.0       | 6.0       | 3.0       | 4.0       | 5.0       | 2.0       | 3.0       | 4.0       |
|        | T (%)    | -4.5      | -6.0      | -6.0      | -3.5      | -5.0      | -5.0      | -2.5      | -4.0      | -4.0      | -2.0      | -3.0      | -3.0      |
|        | Is (%)   | -1.5      | -4.0      | 0.2       | -1.0      | -3.5      | 0.0       | -1.0      | -3.0      | -1.5      | -0.5      | -2.5      | -2.5      |
| High   | P (%)    | 0.0       | 0.0       | 0.7       | -2.0      | -0.5      | -0.3      | -4.0      | -1.0      | -0.5      | -2.0      | -1.5      | -1.0      |
|        | A (%)    | 6.0       | 8.0       | 8.0       | 5.0       | 6.0       | 7.0       | 4.0       | 5.0       | 6.0       | 2.0       | 4.0       | 5.0       |
|        | T (%)    | -5.0      | -7.0      | -7.0      | -4.0      | -6.0      | -6.0      | -3.0      | -5.0      | -5.0      | -2.5      | -4.0      | -4.0      |
|        | Is (%)   | -2.0      | -5.0      | 0.5       | -1.5      | -4.5      | -1.0      | -1.0      | -4.0      | -2.0      | -0.5      | -3.5      | -3.0      |

2.6. Analysis of the Prediction Results of the Peak Carbon Emission in Beijing, Tianjin and Hebei Provinces

Based on the above-mentioned parameters of population, per capita GDP, energy intensity, and the proportion of influencing factors, the Beijing-Tianjin-Hebei economic development scenario under the low-, medium-, and high-level models of the 2016-2035 period is forecasted under different scenarios. Whether to reach the peak and peak carbon emissions in 2030. To achieve the goal of Beijing-Tianjin-Hebei carbon emissions reaching its peak within 2030, the Beijing-Tianjin-Hebei region will form a good demonstration effect, and it is necessary to control the growth rate of variables such as population and per capita GDP. Therefore, a variety of combination development modes such as high and low modes, medium and low modes, and high school modes are set to select the peak in the shortest time or to reach the lowest peak. In addition, in order to show the relationship between the change of carbon peak and the population, per capita GDP, energy intensity, and parameter rate of the secondary production ratio, the peak parameter and the peak time are obtained by increasing the variable parameter rate based on the best model. / Economic Development / Technological Progress / Optimization of Industrial Structure.

3. The Conclusion

This paper forecasts the peak emission of carbon emissions under different scenarios in Beijing, Tianjin and Hebei based on the extended forecasting model and scenario analysis. It was found that the similarity between the peak time and the peak factor of Beijing-Tianjin-Hebei was relatively high, and the target of carbon emissions peaking around 2030 could be achieved. The main conclusions are:

1) Based on the development status of Beijing, Tianjin and Hebei's population, economy, industrial structure and other aspects, Beijing-Tianjin-Hebei is similar to the optimal development model chosen to achieve the peak of carbon emission as early as possible under the coordination condition. It is suggested that Beijing should choose the high and low model, Tianjin and Hebei choose the high and low + industrial optimization model as the current social and economic development model, the carbon emission peak time is 2025 years, the peak size is: 163,500 tons, 18,312,260 tons, 74,737,800 T.

2) The peak single-factor analysis of carbon emissions shows that the population of Beijing, Tianjin and Hebei has an important impact on the peak time and peak size. The population is the main influencing factor to advance the peak time and reduce the peak value; the per capita GDP of Beijing and Hebei is the peak. In terms of the main factors influencing the time delay and increasing the peak value, the per capita GDP of Tianjin only affects the peak value; the impact of Beijing's emission intensity on the peak value is smaller, and the impact on peak time is greater. Tianjin's carbon...
emission intensity has a greater impact on peak time and peak size. The emission intensity of carbon in Hebei only affects the peak carbon emission; the decrease in the proportion of Beijing secondary production leads to the change of peak time and quantity, and the proportion of Tianjin-Hebei secondary production does not affect the peak time and only affects the peak value.

(3) In the future development, the coordinated development of Beijing, Tianjin, and Hebei will be further promoted and the synergy will reach its peak at an early date. The population of the population-controlled urban population should be channelled to the surrounding areas through industrial transfer; the technical coordination will be realized, the innovation capability will be significantly improved, and the urban carbon footprint will be suppressed. Increase; Beijing-Tianjin-Hebei industrial structure continues to be optimized, industrial transformation and upgrading; the economy is further developed, but on the basis of healthy economic development, it is necessary to control excessive economic development and lead to increased carbon emissions. In the end, we will strive to build a Beijing-Tianjin-Hebei metropolitan area where the economy is more prosperous, the society is more harmonious, the ecology is more beautiful, and the people are happier.

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