Decomposition Analysis of Energy Carbon Emission Factors in Beijing-Tianjin-Hebei

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Abstract: With the rapid economic development of Beijing-Tianjin-Hebei region, the problem of environmental pollution cannot be ignored. Especially in recent years, the haze weather, the increase of carbon dioxide emissions, the development of Beijing, Tianjin and Hebei has brought a negative impact. Now, the primary energy consumption of the three regions of Beijing, Tianjin and Hebei is decomposed into five factors including population, economy, industrial structure, energy intensity and energy consumption structure by using LMDI decomposition method. The results show that: overall population and per capita GDP promote the growth of carbon emissions, and overall industrial structure effect, energy intensity effect and energy consumption structure factors inhibit the growth of carbon emissions. The energy intensity of the secondary industry and the tertiary industry has a very significant inhibiting effect on the growth of carbon emissions.

Key words: Beijing-Tianjin-Hebei; carbon emission; STIPART model; LMDI model.

1. Introduction and literature review

In recent years, the Beijing-Tianjin-Hebei coordinated development strategy has risen to the level of the country's major development strategy. President Xi Jinping emphasized that realizing the coordinated development of Beijing, Tianjin and Hebei is the need of ecological civilization construction, the need for coordinated development of resources, environment and economic development, and a major strategy for national development. The Beijing-Tianjin-Hebei region should adhere to mutual benefit and win-win results, give full play to their respective advantages, make up for the shortcomings in development, and push forward the pace of coordinated development. Therefore, in the process of low-carbon development, it is the general trend to give full play to their respective advantages, unify their goals, and achieve the maximum energy conservation and emission reduction in the region.

Foreign scholars have conducted systematic research on the factors affecting carbon emissions. Vinuya[1] et al. (2010) decomposed the factors affecting US carbon emissions growth into five parts. The results show that the reduction of fossil energy consumption ratio, the reduction of energy carbon emission coefficient and the improvement of energy efficiency offset the population and per capita GDP growth. The impact of increased carbon emissions has contributed. Xin Tian [2] et al. (2013) analyzed the impact of changes in economic and technological factors on Beijing's carbon emissions. The empirical results show that industrial structure changes and final demand levels are the main influencing factors of carbon emission changes. Qi Yawei [3](2014) decomposed China's carbon emission factors...
into scale effect, technology effect, industrial structure effect and regional spatial structure effect; Li Haiying[4] (2014) decomposed China's carbon emission intensity into energy intensity effect, energy structure effect, and input Structural effects, import substitution effects, final demand product structure effects, and final product use structure effects, and the influencing factors are classified into production mode and demand mode; Tian Zhonghua[5] (2015) decomposes the factors affecting carbon emission intensity into industries. Energy intensity, carbon emission coefficient, industrial structure and energy consumption structure.

2. Research design

2.1. Selection of decomposition factors
The three regions' energy consumption carbon emissions are decomposed into five aspects: population, economy, industrial structure, energy intensity, and energy consumption structure. Data from Beijing, Tianjin, and Hebei from 2000 to 2014 were selected. The data were obtained from China Energy Statistics Yearbook, National Bureau of Statistics, and Wind Database.

2.2. Inspection of decomposition factors
The stirpat model is an extended environmental impact factor model. In this study, the regression analysis of the stirpat model is first carried out, and the factors such as population, economic growth, industrial structure and energy intensity to be studied are used as explanatory variables to perform regression test of the stirpat model. Through the regression results of the Stirpat model, the degree and direction of the impact of various factors on energy consumption carbon emissions are obtained, which provides preliminary results for analyzing the effects of various factors, and also provides a basis for subsequent LMDI decomposition.

2.3. Quantification of decomposition factors
The stirpat model can generally derive the impact of the selected decomposition factors on energy consumption carbon emissions, but its interpretation is very limited. After the feasibility of the decomposition factor is verified by the stirpat model, the LMDI decomposition of the various factors affecting carbon emissions from energy consumption will be carried out. The LMDI decomposition can accurately and annually decompose the various indicators affecting carbon emissions to determine the quantitative impact of each impact factor on energy consumption carbon emissions.

3. Beijing-Tianjin-Hebei consumption carbon emissions stirpat model

3.1. Model Description
In the 1970s, American ecologist Eric proposed an IPAT relationship that characterizes the environmental impact of economic development. The three factors of population, affluence and technology reflect the environmental impact. The relationship is expressed by these three factors:

\[ I_i = aP_i A_i T_i e_i \]  (1)

The extended IPAT model (Eq. (2)) is STIRPAT, where: \( a \) is the model coefficient; \( b, c, \) and \( d \) represent the elasticity of population, economic, and technical factors, respectively; \( e \) is the residual term.

\[ I_i = aP_i^b A_i^c T_i^d S_i^e Y_i^f e_i \]  (2)

The industrial structure variable \( s \) and the per capita income level variable \( y \) are added on the basis of the stirpat expansion model. For the equation (2), the logarithm of both sides is taken at the same time. The multivariate linear equation of the total carbon emissions is fitted by the ols least squares
method, and the relative contribution of each influencing factor to the total amount of carbon dioxide emissions is obtained.

3.2. Regression analysis
The preliminary regression results show that: population, economic level, energy intensity, industrial structure and living water level are significant factors affecting carbon dioxide emissions, and the structure of primary industry and tertiary industry in industrial structure explanatory variables is not significant. The overall fit of the model is very good, but the collinearity between the explanatory variables is very obvious based on the value of the variance expansion factor. Further consideration is given to the use of stepwise regression and collinearity diagnosis. After stepwise regression to obtain the optimal regression equation results as shown in Table 1, it can be seen that the overall fitting effect of the model is very significant, and the dw value of the collinear diagnosis is 1.534, which is within a reasonable range.

| Independent variable | Regression equation coefficient | Standard deviation | t statistic | p value | Variance expansion factor |
|----------------------|---------------------------------|--------------------|------------|---------|----------------------------|
| X1                   | 0.914                           | 0.016              | 58.776     | 0.000   | 26.643                     |
| X2                   | 0.771                           | 0.036              | 21.671     | 0.000   | 116.708                    |
| X3                   | -0.031                          | 0.009              | -3.372     | 0.002   | 12.260                     |
| X4                   | 0.748                           | 0.010              | 77.191     | 0.000   | 7.423                      |
| X5                   | 0.259                           | 0.020              | 13.025     | 0.000   | 18.833                     |
| X7                   | 0.555                           | 0.016              | 35.358     | 0.000   | 5.039                      |
| X9                   | 0.339                           | 0.043              | 7.911      | 0.000   | 95.469                     |

| Goodness of fit | Sample standard deviation | Sum of residuals | F statistic | Significant p-value | Dw value |
|-----------------|---------------------------|-----------------|-------------|---------------------|---------|
| 1.000           | 0.015                     | 0.009           | 16369.648   | 0.000               | 1.534   |

3.3. Empirical analysis
Through the analysis of the Stirpat model, it can be seen that population, economic level, energy intensity, industrial structure and living standard are indeed significant factors affecting the total amount of carbon dioxide emissions, and can be used as an empirical basis for subsequent LMDI decomposition. From the regression results, it can be seen that the influence of various factors on the total amount of carbon dioxide emissions is population, economic growth, energy intensity, industrial structure and living level, and the ratio of energy intensity of the primary industry to the structure of the secondary industry. Carbon dioxide emissions are negative; the remaining explanatory variables have a positive impact on CO2 emissions. The coefficient of the relationship between population and carbon dioxide emissions is 0.914, which means that for every 1% increase in population, total carbon dioxide emissions rise by 0.91%. The coefficient of the relationship between per capita GDP and carbon dioxide emissions is 0.771. The coefficients of the relationship between energy consumption intensity and carbon dioxide emissions of the three major industries are -0.031, 0.748, and 0.259, respectively. The coefficient of industrial structure and carbon dioxide emissions is 0.555. The coefficient of relationship between living standards and carbon dioxide emissions is 0.339.

4. Beijing-Tianjin-Hebei energy consumption carbon emission LMDI model

4.1. Model Description
According to the LMDI model, the total amount of carbon emissions can be decomposed into changes caused by population effects, changes caused by economic growth effects, changes caused by industrial structure effects, changes caused by energy intensity effects, and changes in energy structure effects. the amount.
4.2. **Decomposition results**

Based on 2011, the extended kaya model and LMDI decomposition method are used to decompose the energy consumption carbon emissions of Beijing, Tianjin, Hebei and Beijing-Tianjin-Hebei from 2011 to 2018, and calculate the annual and cumulative effects of various decomposition factors. The decomposition results are shown in Tables 2 ~ 4.

**Table 2. Decomposition Analysis Table of Incremental Effect Factors of Beijing Energy Consumption Carbon Emissions**

| Year       | Population | Economic Growth | Industrial structure | Energy intensity | Energy consumption structure | Comprehensive effect |
|------------|------------|-----------------|----------------------|-----------------|-----------------------------|----------------------|
|            | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change |
| 2011-2012  | 42         | 42               | 310       | 310             | -84             | -84               | -236            | -236            | -16           | -16             | 16             | 16             |
| 2012-2013  | 62         | 104              | 267       | 577             | -85             | -169              | -329            | -564            | -10           | -26             | -95            | -79            |
| 2013-2014  | 50         | 154              | 275       | 851             | 30              | -139              | -241            | -806            | 14            | -12             | 127            | 48             |
| 2014-2015  | 60         | 213              | 383       | 1234            | 43              | -96               | -216            | -1022           | -10           | -23             | 259            | 307            |
| 2015-2016  | 75         | 289              | 291       | 1525            | -79             | -175              | -216            | -1237           | -5            | -28             | 66             | 373            |
| 2016-2017  | 71         | 360              | 324       | 1849            | -102            | -277              | -240            | -1477           | -9            | -37             | 44             | 417            |
| 2017-2018  | 86         | 446              | 427       | 2276            | -75             | -352              | -344            | -1821           | -17           | -54             | 77             | 494            |

**Table 3. Decomposition Analysis Table of Incremental Effect Factors of Carbon Emissions in Tianjin Energy Consumption**

| Year       | Population | Economic Growth | Industrial structure | Energy intensity | Energy consumption structure | Comprehensive effect |
|------------|------------|-----------------|----------------------|-----------------|-----------------------------|----------------------|
|            | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change |
| 2011-2012  | 86         | 231              | 313       | 1505            | 2               | 29                | -342            | -1248           | -2            | 54              | 55             | 571            |
| 2012-2013  | 75         | 306              | 121       | 1626            | -23             | 6                 | -7              | -1255           | 8            | 63              | 174            | 746            |
| 2013-2014  | 100        | 406              | 264       | 1890            | -6              | 0                 | -404            | -1659           | -24           | 39              | -70            | 676            |
| 2014-2015  | 77         | 483              | 293       | 2183            | -2              | -2                | -265            | -1895           | -8            | 31              | 124            | 800            |
| 2015-2016  | 83         | 566              | 176       | 2359            | -9              | -10               | -58             | -1953           | 9             | 40              | 202            | 1001           |
| 2016-2017  | 84         | 650              | 149       | 2359            | -19             | -29               | -255            | -2208           | 5             | 45              | -35            | 966            |
| 2017-2018  | 61         | 711              | 114       | 2622            | -20             | -49               | -139            | -2347           | -2            | 44              | 15             | 981            |
Table 4. Decomposition Analysis Table of Incremental Effect Factors of Hebei Energy Consumption Carbon Emissions

| year     | population | Economic Growth | Industrial structure | Energy intensity | Energy consumption structure | Comprehensive effect |
|----------|------------|-----------------|----------------------|-----------------|-----------------------------|---------------------|
|          | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change | Annual change | Cumulative change |
| 2011-2012 | 67          | 340             | 1590               | 6610            | -60           | 557             | -946          | -2652           | 91           | 116             | 993           | 6561             |
| 2012-2013 | 70          | 410             | 726                | 8200            | 192           | 251             | -271          | -2923           | 3            | 119             | 221           | 6782             |
| 2013-2014 | 251         | 661             | 1630               | 8926            | -306          | 330             | -1451         | -4375           | 67           | 185             | 576           | 7358             |
| 2014-2015 | 78          | 740             | 2161               | 10556           | 79            | 507             | -1023         | -5398           | -7           | 178             | 1386          | 8744             |
| 2015-2016 | 84          | 824             | 967                | 12717           | 177           | 371             | -592          | -5990           | -3           | 175             | 319           | 9064             |
| 2016-2017 | 81          | 905             | 814                | 14497           | -137          | 260             | -840          | -6829           | 19           | 194             | -36           | 9027              |
| 2017-2018 | 90          | 996             | 349                | 14847           | -111          | 115             | -577          | -7406           | -13          | 181             | -295          | 8733              |

4.3. Empirical analysis

Through a comparative study of the decomposition factors of carbon emissions from energy consumption in Beijing, Tianjin and Hebei, it can be found that the three countries have similar decomposition results on the decomposition factors of carbon emission contribution rate. Both the population factor and the economic growth factors have a positive contribution rate to the increase of carbon emissions in the three places. The energy intensity factor has a significant inhibitory effect on the carbon emission growth of the three places; the cumulative effect of industrial structure and energy consumption structure on carbon emissions. The impact is relatively weak.

5. Main conclusions and recommendations

5.1. Main conclusions

Through the empirical results of the stirpat model, it can be obtained that population factors, economic growth factors, industrial structure factors, and energy intensity factors are all significant factors affecting the total amount of carbon dioxide emissions. Through the LMDI model, the specific effects of various factors on carbon emissions in Beijing, Tianjin and Hebei are obtained. Results: The population and per capita gdp have a carbonation effect on carbon emissions in Beijing. The industrial structure, energy intensity and energy consumption structure are The carbon emissions in Beijing are generally reflected in the carbon reduction effect. For Tianjin, the population, per capita gdp, and energy consumption structure are generally carbon-increasing effects on carbon emissions. Industrial structure and energy loudness are generally carbon reduction in carbon emissions. Effect; For Hebei Province, population, per capita gdp, industrial structure, and energy consumption structure all show carbonation effects in carbon emissions. Energy intensity is generally carbon reduction in carbon emissions.

5.2. Recommendations

Analyze and study the factors affecting Beijing's energy consumption carbon emissions, and explore its deep-seated reasons to provide theoretical support for the government to better promote carbon emission reduction. Based on the above conclusions, the policy recommendations in this paper are:

(1) Adjust the industrial structure.
Strengthen the upgrading of the secondary industry, and use the technological advantages of Beijing and Tianjin to enhance the added value of manufacturing and manufacturing chain links. Broadening the development of the tertiary industry, improving the coverage of the tertiary industry services and the low carbon value of the industry are the key points and points for Hebei Province to focus on industrial upgrading.

(2) Optimize energy structure

Beijing's energy structure adjustment has played a certain role in carbon emission reduction, which is mainly related to the development policy of Beijing to use oil to replace coal. Tianjin and Hebei currently mainly consume energy or coal, so the energy structure effects of Tianjin and Hebei have contributed to local carbon emissions. In the future development plan, Beijing-Tianjin-Hebei should pay attention to reducing coal consumption, gradually replacing coal consumption with oil and gas, and actively developing new energy, developing new technologies, and maintaining economic development with renewable and green energy. Thereby achieving the emission reduction target.

(3) Strengthen the population control of Beijing-Tianjin-Hebei and optimize resource allocation

The influence of population factors on the economic development of Beijing-Tianjin-Hebei and carbon emission reduction is an important factor, and the most important factor in population regulation is to solve the causes of population movement. For Beijing to carry out the criteria for population and industrial access, and the many benefits that Beijing enjoys, it is possible to distribute benefits to Tianjin and Hebei, and to guide the spread of population and industries to surrounding cities. For example, establish a rapid transportation system in the metropolitan area, realize intercity railway transit within the scope of Beijing-Tianjin-Hebei, and promote the integration of public services and social security.

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