IOP Conf. Series: Earth and Environmental Science 111 (2018) 012025 doi:10.1088/1755-1315/111/1/012025

Analysis on Influence Factors of CO_2 Emission in Hebei

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Abstract. China has become the world's largest carbon emitter in the world, while Hebei province, dominated by heavy industry, contributed a mass of carbon emissions for the whole country. It was necessary for Hebei to adjust its industrial and energy structure to reduce carbon emissions. This paper analysed the total energy consumption and CO_2 emissions in Hebei from 2000 to 2015, and utilized the Logarithmic Mean Di index Method to decompose CO_2 emissions emitted by energy consumption. Six factors were decomposed from the total emissions and the Lagrange descriptions as well as the Eulerian description were both employed to analyse these factors` trajectory of change. The results discovered that the CO_2 emissions by energy consumption in Hebei were mainly stimulated by economic scale expansion, especially the production growth of secondary industry. While the energy intensity become the major restraint for causing CO_2 emissions declining. The impacts of other factors were not very remarkable. Finally, some macroscopic advices were offered to control carbon emissions in Hebei.

1. Introduction

As an industrial region, the development of industrial system began to take shape in Hebei. Conditioned by natural resources and location, the development patterns of relying on resources did not change a lot and the heavy industries like steel, coal, chemical, still pillared the economic growing of Hebei province. And this pattern left CO_2 emissions emitted by production activities on the rise.

Factors decomposition analysis was an efficient way to figure out influence factors on carbon emissions growing. And this study utilized Log-Mean Division Index (LMDI) method to study CO_2 emission in Hebei and figure out essential factors in it.

There has been much research on carbon emissions through LMDI method, such as Zhou and Ang (2008) [1], Wei et al. (2008) [2], Hammond and Norman (2012) [4]. Roinioti and Koroneos (2017) [5] decomposed CO_2 emissions from energy use in the context of the economic crisis in Greece. Lin and Tan (2017) [6] explored the main factors influencing CO_2 emissions in China and further estimated the potential carbon emissions in energy intensive industries in China for the future. In regard to the factors decomposed, there were usually three factors [7, 8], four factors [9, 10] and five factors [11-13]. For instance, research by Jiang et al. (2017) [14] discussed the underlying drivers of economic carbon emissions through decomposing four factors. The results indicated that economic expansion were responsible for CO_2 emissions growing while the sectoral energy intensity and structure changes caused CO_2 emissions declining.

In this paper, it was believed that the change of CO_2 emissions in Hebei province was decomposed six factors: the economic scale, population quantity, energy structure, energy intensity, industrial structure and carbon emission coefficient. Compared to other literatures, population was taken into consideration and per capita GRP (Gross Regional Production) was on behalf of the economic factor to eliminate the impact of population change on carbon emissions in Hebei province.

2. Material and methodology

2.1 Material

The employed data was taken from the China Energy Statistics Yearbook and Hebei Economic Yearbook (2000-2015). And the gross regional production (GRP) in Hebei was expressed in constant prices using 2000 as benchmark year.

The industry in Hebei was divided into four parts: a) the first industry, namely agriculture; b) modern industry; c) construction industry and d) the third industry, namely modern service industry. As respect to classification of energy resources, primary energy was divided into four parts: a) coal; b) crude oil; c) natural gas; d) primary electricity.

Total emissions of CO_2 in was calculated coefficients of standard coal employed the findings of NDRC Energy Research Institute and coefficients of CO_2 emissions was cited from GB-T25892008.

$$C = \sum_{j=1}^{n} E_j \bullet \sigma_j \bullet \omega_j \tag{1}$$

2.2 Methodology

The process and formula of CO_2 emission decomposition were as follows. This change can be composed into six effects: ΔC_U represents the change caused by variation of carbon emission intensity, defined as effect of CO_2 intensity; ΔC_M represents the change caused by variation of Energy-resource structure, defined as effect of energy structure; ΔC_I represents the change caused by variation of Energy intensity of each sector, defined as effect of energy intensity; ΔC_S represents the change caused by variation of Industrial structure, defined as effect of industrial structure; ΔC_{AY} represents the change caused by variation of GDP per capita, defined as effect of economy; ΔC_P represents the change caused by variation of population scale, defined as effect of population.

$$\begin{aligned}\Delta C &= C^T - C^0 \\ &= \sum_{i=1}^{m} \sum_{j=1}^{n} U_{ij}^T \bullet M_j^T \bullet I_i^T \bullet S_i^T \bullet AY^T \bullet P^T \\ &- \sum_{i=1}^{m} \sum_{j=1}^{n} U_{ij}^0 \bullet M_j^0 \bullet I_i^0 \bullet S_i^0 \bullet AY^0 \bullet P^0 \\ &= \Delta C_U + \Delta C_M + \Delta C_I + \Delta C_S + \Delta C_{AY} + \Delta C_P\end{aligned} \tag{2}$$

Further decomposition of CO_2 intensity effect was conducted with Eq (4) and Eq (5). And other effect also can ben decomposed in a similar way. However, it was noted that according to IPCC's hypothesis, carbon emission coefficient of a certain energy source can be considered unchanged, namely ΔC_U =0.

$$\Delta \sum_{i=1}^{m} \sum_{j=1}^{n} B_{ij} \ln(\frac{}{U_{ij}^0}) \tag{3}$$

$$B_{\mathrm{ij}} = \frac{C_{ij}^T - C_{\mathrm{ij}}^0}{InC_{ij}^T - InC_{ij}^0} \tag{4}$$

3. Energy Consumption and CO_2 Emissions in Hebei Province

3.1 Energy Consumption

After entering twenty-first Century, economy of Hebei province has entered a stage of rapid development with regional GDP increasing exponentially. In the process of urbanization and industrialization, a great deal of energy was demanded. As can be seen from Figure.3-1, the total energy consumption and GRP growth trend was about the same: real GRP in Hebei rose from 504.40 billion RMB to 713.29 billion RMB with an average annual growth rate of 2.43%; while total energy consumption rose to 75.62 million tons from 36.22 million tons with an average annual growth rate of 5.38%, which exceeded the average speed of GRP growing. However, total energy consumption has gradually declined since 2012.

Like the whole country, Hebei maintained energy consumption structure with coal dominating. Hebei also was an industrial province in China. The industrial output, especially the heavy industry, promoted provincial economic growth overwhelmingly. Before 2009, energy consumption of industrial sector accounted for over 80%, and dropped to about 75% of the total consumption after 2010. While the share of modern service gradually increased to more than 17%, even 19% since 2010.According to statistics, total energy consumption, total coal consumption and industrial energy consumption in Hebei ranked the second, the fourth and the third respectively in 34 provinces of China.

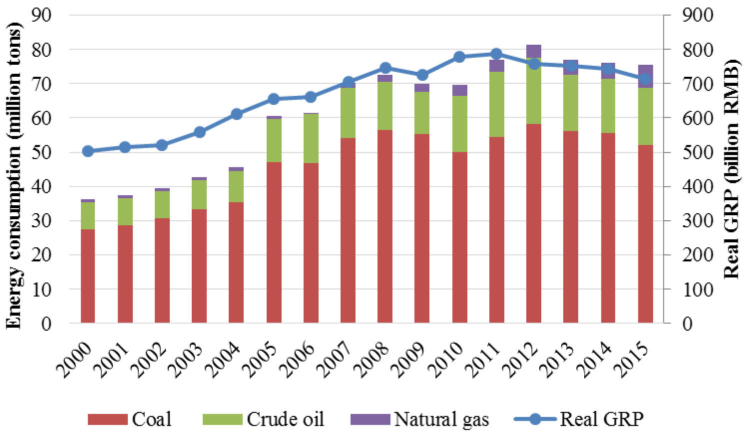

Figure.3-1. Hebei`s GRP and energy consumption in 2000-2015.

3.2 CO_2 Emissions

CO_2 emissions from three primary energy resources in Hebei calculating by Eq.6 were shown in Figure.3-2. Two periods was divided into on the basis of variation: a) the growing stage: 2000-2008 b) the undulate stage: 2009-2015. In the growing stage, total CO2 emissions increased with 9.51% per year. And in the undulate stage, CO_2 emissions kept around 180 million tons in total with fluctuation, and reached a maximum of 207.17 million tons in 2012. According to You (Per capita carbon emission of Hebei Province

From an industrial point of view, industry emitted the largest part of CO_2 emissions, climbing 9.30% per year and occupying over 80% in the growing stage. Lined with energy consumption, emissions of modern service sector markedly increased and was more than 15% in the undulate stage, where the proportion of industrial CO_2 emissions were less than 80%.

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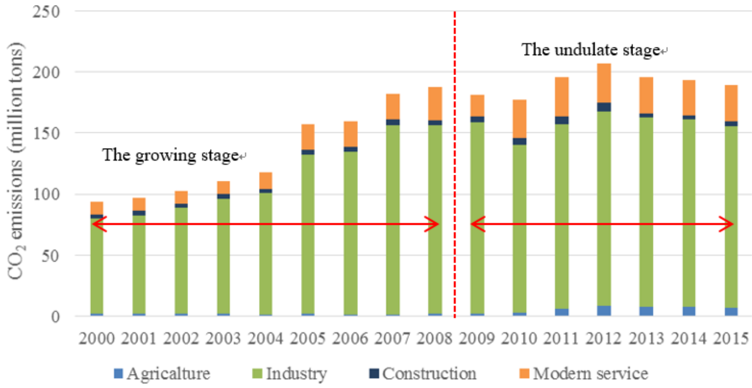

Figure.3-2. Hebei`s CO_2 emissions in 2000-2015.

4. Results

A LMDI model was utilized to decompose six factors responsible for Hebei`s CO_2 emissions from 2000 to 2015. On the basis of *2.2*, the effect of CO_2 emissions intensity equalled to zero. And the concrete calculation process has been completed in *2.2*. There were two choices of base year in this paper: a) Lagrange description method: unfixed base period, which meat the previous year and the total effect of CO_2 emissions in Fig.4-1 was an increment from the previous year; b) Eulerian description method: fixed base period, which meant 2000 was the base year, meaning the total effect in Fig.4-2was an accumulated increment.

4.1 Results analysis with Lagrange description

As shown in Figure.4-1, the economic scale factor was the factor mainly responsible for CO_2 increasing in the whole process. From 2001 to 2011, Hebei`s the growth of CO_2 emissions has been strongly driven by provincial economic development. And in 2011, the economic effect reached the maximum with contributing 31.58 million tons CO_2 in total. Then, contribution of this positive factor began to decline and in 2015 this positive factor only contributed about 1.29 million tons CO_2.

The energy intensity effect was the main factor causing the declining in CO_2 emissions. As with efficiency of energy utilization, energy intensity reflected regional comprehensive technical level: the more technology advanced, the bigger energy efficiency, the smaller energy intensity namely the less energy consumption per unit of GDP and the less carbon emissions. Except for 2007, the effect of energy intensity was negative, and achieved negative maximum in 2010. In 2009-2010 and 2012-2015, the effect of energy intensity exceeded the economic, which led to a decline in CO_2 emissions in these years.

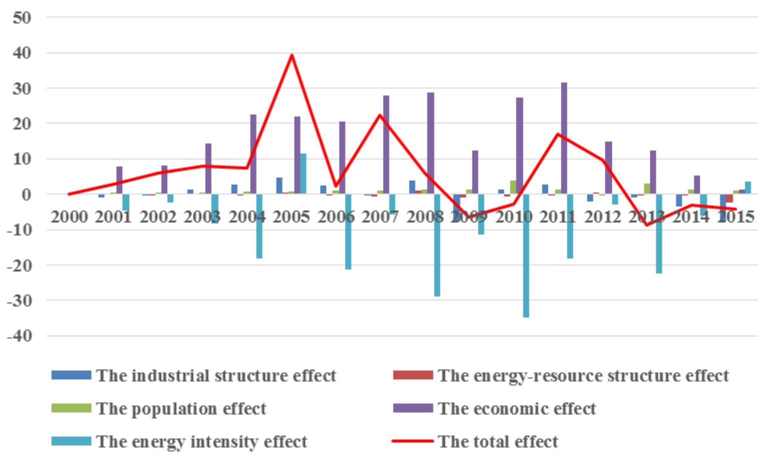

Figure.4-1. Decomposition Analysis of CO_2 emissions with unfixed base year.

Other effects were smaller than the economic and the energy intensity. Contribution of the industrial structure effect varied in the whole process and kept causing CO_2 emissions declined 14.39 million tons since 2012. And the energy-resource structure was negative factor while the population influenced CO_2 emissions positively. But both of them impacted on carbon emissions relatively lightly when comparing with the effect of economic and energy intensity.

4.2 Results analysis with Eulerian description

According to *3.2*, two stages of CO_2 emissions were divided: the growing stage (2000-2008) and the undulate stage (2009-2015). In the growing stage, all factors, except for energy intensity, influenced carbon emissions positively. And the total effect growing rapidly for the reason that the economic effect was obviously bigger than that of energy intensity. To a certain extend changes in industrial structure enhanced the total effect in this stage. The most distinctive feature in undulate stage was that energy intensity strengthened its negative influence. This huge inhibition and no increasing economic effect lowered the growing speed of CO_2 emissions and controlled the total effect keeping under 110 million tons since 2012. Compared with the previous phase, the effect of industrial structure generally weakened and even was responsible for -1.85 million tons in 2015. The population effect strengthened in the whole period although its contribution for the total effect was less than 15 million tons. And because of few changes of energy-resource structure the effect of it was unobvious in 2000-2015.

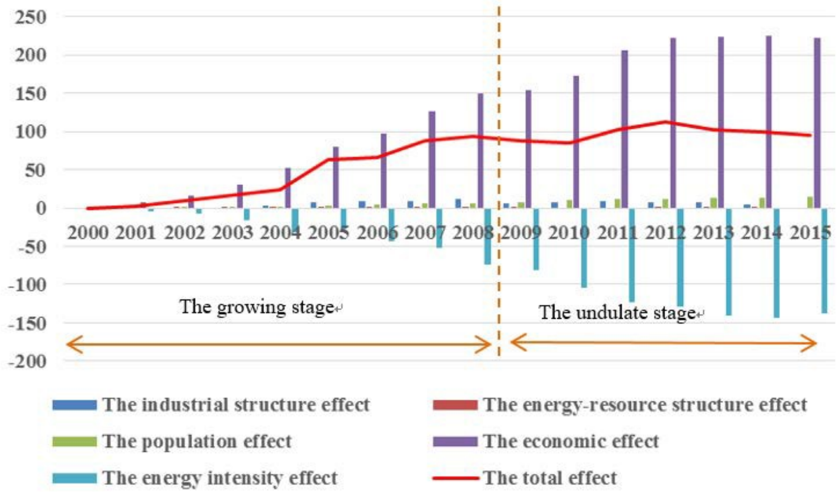

Figure.4-2. Decomposition Analysis of CO_2 emissions with fixed base year.

5. Discussion

On the foundation of previous studies, a LMDI model was employed to analyse factors of CO_2 emissions in Hebei province during 2000 -2015. Six factors were decomposed and impact by these factors was quantified. Effects of these factors was analysed with Lagrange description and Eulerian description method. The results can be concluded into four points.

a) Both of Lagrange and Euler description method showed that compared with other positive factors, the economic effect represented by per capita GRP was the maximum factors, which meant economic growth was a powerful driving force for the aggrandizement of CO_2 emissions in Hebei province.

b) The decline of energy intensity mainly leading CO_2 emissions to inhibit in Hebei province. During 2000 -2015, the energy intensity in Hebei dropped by 0.46.This change had saved over 100 million tons CO_2 emissions each year since 2010.

c) The factor of population was responsible for part of carbon emissions increment. Impacts of industrial structure varied from positive to negative ceaselessly but began to lowered CO_2 emissions after 2012. This change was in accordance with the reform of industrial structure in Hebei, which required the proportion of the modern service sector raised and the industry sectors declined.

d) Compared with other factors, the energy-resource structure had the least influence on CO_2

emissions. The reason was that the proportion of coal, oil and natural gas in primary energy consumption did not change much during 2000-2015.

Some suggestion can be made to decrease CO_2 emissions in Hebei province. First of all, energy efficiency should be improved through technological research and application, which means reduce energy intensity and intensify negative influence on CO_2 emissions. Secondly, reform on industrial structure adjustment should be continued. Policy measures of increasing the production proportion of the modern service sector ought to be implemented. Last not the least; popularize usage of natural gas and renewable energy to shrink percentages of coal and oil in energy consumption.

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