A Study on Decoupling of Carbon Emissions from Beijing-Tianjin-Hebei Transport Industry

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Abstract. As the world's largest carbon emitter, the Chinese government is actively taking responsibility for reducing emissions and formulating relevant policies to achieve a low-carbon economy. The transportation industry is the third largest greenhouse gas emission source after the power industry and the steel industry in China, so the transportation industry is an important sector of carbon emission reduction in China. The Beijing-Tianjin-Hebei region is one of the supporting platforms for China's strong competitiveness in the international economic system, but its transportation system development is not balanced, and there are also great differences in energy consumption and carbon emissions. Therefore, it is of great significance to study the correlation between carbon emission and economic growth in The Beijing-Tianjin-Hebei region. In this context, this paper takes the Beijing-Tianjin-Hebei transportation industry as the research center, explores the decoupling relationship between its industry growth and carbon emissions, and gives relevant conclusions.

1. Introduction

At present, addressing global climate change has become one of the core tasks in the process of sustainable development for all countries in the world. As the world's largest carbon emitter, the Chinese government is actively taking responsibility for reducing emissions and formulating relevant policies to achieve a low-carbon economy.

The transportation industry is the third largest greenhouse gas emission source after the power industry and the steel industry in China, so the transportation industry is an important sector of carbon emission reduction in China. The Beijing-Tianjin-Hebei region is one of the supporting platforms for China's strong competitiveness in the international economic system, but its transportation system development is not balanced, and there are also great differences in energy consumption and carbon emissions. Therefore, it is of great significance to study the correlation between carbon emissions from the transportation industry and economic growth in Beijing-Tianjin-Hebei region to realize the goal of stable economic growth and parallel low-carbon transportation in the region.

In 2002, in order to explore the correlation between economic development and environmental pollution[5], OECD put forward the "decoupling" theory to describe the slowing or blocking of the coupling between economic growth and pollution emission. Tapio(2005) [7]constructed a decoupling model to study the relationship between greenhouse gas emissions and economic growth in Europe by introducing traffic volume as an intermediate variable, and defined 8 decoupling states. Since then, Tapio decoupling model has been mostly used by scholars for relevant studies.
Through combing existing literature, it is found that domestic and foreign scholars mainly use decoupling theory to study the decoupling relationship between macroeconomic growth and greenhouse gas emissions, but rarely involving transportation and transportation. In addition, most of the research focuses on the national level. Even for the regional level of China, most of the research focuses on the Yangtze River Delta region and the central region, or a single administrative province, and less on the Beijing-Tianjin-Hebei region. Therefore, in this context, this paper takes the Beijing-Tianjin-Hebei transportation industry as the research center, explores the decoupling relationship between its industry growth and carbon emissions, and gives relevant conclusions.

2. MEASUREMENT

2.1. Carbon emission calculation model establishment and data description

At present, China does not directly monitor the carbon emission data of transportation. Most of the carbon emission data are obtained based on the calculation of energy consumption. There are two ways to calculate the carbon emission of transportation energy consumption. The top-down method is to obtain the carbon emission by multiplying the energy consumption of transportation vehicles by the carbon emission coefficient of various energy sources. The bottom-up calculation method is mainly to calculate the carbon emissions based on the data of different traffic types, such as mileage, energy consumption per unit of driving and vehicle ownership[1]. In view of the availability of data, this paper adopts a top-down approach to estimate the carbon emissions from energy consumption in the transportation sector of The Beijing-Tianjin-Hebei region from 1998 to 2017.

The recommended formula for the 2006 IPCC Guidelines for National GREENHOUSE Gas Inventories is as follows:

\[ E_{CO_2} = \sum_j E_j \times EF_j \]

Where \( E_{CO_2} \) is the total amount of \( CO_2 \) emissions caused by fuel consumption, \( j \) is the type of energy (such as gasoline, diesel, natural gas, etc.), \( E_j \) is the energy consumption (10,000 tons of standard coal), and \( EF_j \) is the \( CO_2 \) emission factor.

\[ EF_j = \text{average calorific value of energy } j \times \text{carbon content of unit calorific value of energy } j \times \text{carbon oxidation rate } \times \frac{44}{12}. \]

According to the formula to calculate the transport carbon emissions of the Beijing-Tianjin-Hebei region, because of the transportation energy consumption data is difficult to obtain, and storage and little energy consumption of the postal service, based on the calendar year of the China energy statistical yearbook of transportation, warehousing and postal service approximate alternative transportation energy consumption, energy consumption data for classification don't energy consumption data in 1998-2017[8]. Secondly, the coefficient of energy consumption less standard coal is referred to China Energy Statistical Yearbook. The \( CO_2 \) emission factor is referred to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. In addition, in view of the unavailability of data of some years, this paper estimated the carbon Emission of the transportation sector in Beijing-Tianjin-Hebei region in these years according to the total carbon Emission Accounts of Beijing, Tianjin and Hebei region given by China Emission Accounts and Datasets (the details are not available for the space limited). The specific calculation process is as follows:

\[ E_{CO_2} = \sum_{i=1}^{n} E_i \times EF_j \]

Where, \( i \) is the region, \( n=3 \), and the sum is the total \( CO_2 \) emission caused by fuel consumption in the three regions of Beijing, Tianjin and Hebei.

2.2. Analysis of carbon emission calculation results of Beijing-Tianjin-Hebei Transportation Industry

The energy consumption of the transportation industry in The Beijing-Tianjin-Hebei region calculated by this paper is shown in Figure 1.
As can be seen from Figure 1, in the time dimension, the CO2 emissions of the Beijing-Tianjin-Hebei transport sector showed an overall increase from 26.52 million tons of standard coal to 84.86 million tons of standard coal from 1998 to 2017. After 2012, the economic development of Beijing-Tianjin-Hebei region entered a new normal, and the growth rate of CO2 emissions in the transportation sector slowed down significantly, or even showed a downward trend. In 2015, the growth began to resume.

From the perspective of spatial dimension, the carbon emission trend of the transportation sector of the three provinces and cities in Beijing, Tianjin and Hebei is consistent with the overall carbon emission trend. Before 2006, the carbon emission of the three provinces and cities was the largest in Hebei, followed by Beijing and the last in Tianjin. Since 2006, Beijing has surpassed Hebei and maintained the first place in carbon emission on average until 2017. Beijing's carbon emissions grew at an average annual rate of 15.2%, while Hebei's grew at an average annual rate of 8.7%. Carbon emissions from Tianjin's transportation industry grew steadily, from 5.36 million tons to 14.4577 million tons, with an average annual growth rate of 8.5 percent, lower than that of Beijing and Hebei.

3. DECOUPLING ELASTICITY ANALYSIS

3.1. Model building

Tapio introduced the concept of "decoupling elasticity" on the basis of OECD decoupling model, redefined the concept of decoupling and refined the level of decoupling. The basic formula is:

$$\varepsilon = \frac{\% \Delta CO_2}{\% \Delta GDP}$$

In above equation, $\varepsilon$ is the decoupling elasticity index, $\% \Delta CO_2$ is the rate of change of carbon emissions, $\% \Delta GDP$ is the rate of change of GDP. According to Tapio's decoupling theory and referring to the research of Zhou Yinxian (2016), this paper takes $CO_2$ to represent transportation carbon emission, $GTO$ to represent the added value of transportation industry, $\% \Delta GTO$ to be the rate of GDP change of transportation industry. The decoupling elasticity index $DE(CO_2,GTO)$ between traffic carbon emission and industry economic growth is constructed, as shown in Equation:

$$DE(CO_2,GTO) = \frac{\Delta CO_2/CO_2}{\Delta GTO/GTO}$$

In order to further analyze the causes of decoupling of transportation carbon emissions, the decoupling elasticity index $DE(CO_2,GTO)$ is decomposed as follows:

$$\frac{\Delta CO_2/CO_2}{\Delta GTO/GTO} = \frac{\Delta CO_2/CO_2}{\Delta E/E} \times \frac{\Delta E/E}{\Delta GTO/GTO}$$

Where $E$ stands for energy consumption of transportation industry; $\frac{\Delta CO_2/CO_2}{\Delta E/E}$ is the emission reduction elasticity between traffic carbon emission and energy consumption, represented by $DE(CO_2,E)$; $\frac{\Delta E/E}{\Delta GTO/GTO}$...
is the energy saving elasticity between energy consumption and the added value of transportation industry, which is used to measure the energy utilization efficiency of transportation industry and expressed by \( DE_{(E,GTO)} \), namely:

\[
DE_{(CO_2,GTO)} = DE_{(CO_2,E)} \times DE_{(E,GTO)}
\]

\%\(\Delta CO_2 \), \%\(\Delta E \) and \%\(\Delta GTO \) represent the change percentage of traffic \( CO_2 \) emissions, energy consumption and value added respectively. The GTO data comes from the statistical yearbook of all provinces and cities on the added value of transportation, warehousing and postal services. To increase the comparability of the data, this paper takes 1998 as the base year for index deflating.

3.2. Decoupling state and evolution

This paper calculates the decoupling elasticity, energy saving elasticity and emission reduction elasticity of traffic carbon emission and industrial economic growth in the Beijing-Tianjin-Hebei region from 1998 to 2016. The calculation results are shown in Figure 2.

![Figure 2. Elasticity of energy conservation, emission reduction and decoupling from 1998 to 2016](image)

In Figure 2, the emission reduction elasticity of Beijing, Tianjin and Hebei in 2004 and 2006 is shown as outliers, so it is eliminated. And the traffic between carbon emissions and energy consumption reduction elasticity in addition to negative in 2008, other years are positive, that carbon dioxide emissions and energy use most of the year is gone, and carbon dioxide increases faster than energy consumption growth year more, reduction effect is not very ideal. The energy saving elasticity, which measures the energy utilization efficiency of transportation industry, is positive in all years except 2008 and 2013 and is mostly less than 1.

It can be seen that the three elasticity has certain volatility, indicating that the data is more reasonable. Among them, the possible reason for the decline of elasticity of energy conservation and emission reduction in 2008 is that the value of \%\(\Delta CO_2 \) in the combined data of Beijing, Tianjin and Hebei in 2008 is positive and within the normal fluctuation range. The value \%\(\Delta GTO \), although also positive, is significantly lower; The value of \%\(\Delta E \) is negative. The content of the data shows that when the energy consumption of Beijing-Tianjin-Hebei region was negative and significantly reduced in 2008, the added value of the transportation industry was positive and lower than the fluctuation range, but the \( CO_2 \) emissions fluctuated normally. By tracing the traffic energy consumption in the Beijing-Tianjin-Hebei region, it is found that the cause of negative energy change is that the heat power consumed by the traffic department in Beijing was significantly higher in 2008, which may be caused by some means of transport or mode of transport.

Combined with the intermediate variable, it can be seen that by 2009, after excluding outliers, the overall fluctuation trend of the three elasticity is basically the same. Since 2010, the transportation energy consumption and energy saving elastic decoupling \( DE_{(E,GTO)} \) and carbon elastic \( DE_{(CO_2,GTO)} \) the dynamic evolution of forms the basic convergence, and transport carbon emissions reduction on energy consumption flexibility \( DE_{(CO_2,GTO)} \) changes in contrast to the first two, and have less effect on the
elasticity of decoupling. The results show that the decoupling of transport carbon emissions from economic growth is mainly determined by the energy conservation elasticity of the transport sector, namely the utilization rate of transport energy, while the contribution of carbon emission reduction technologies corresponding to the elasticity of emission reduction to transport carbon emission has not yet been revealed.

3.3. Decoupling

Combined with the calculation results, the decoupling status of carbon emissions from the transportation industry of Beijing, Tianjin and Hebei from 1998 to 2016 can be obtained, as shown in Table 1.

| Year | \(DE_{(CO_2,GTO)}\) | Decoupling | Year | \(DE_{(CO_2,GTO)}\) | Decoupling |
|------|-----------------|-----------|------|-----------------|-----------|
| 1998 | 0.44            | Weak      | 2008 | 1.83            | Extended negative |
| 1999 | 0.16            | Weak      | 2009 | 0.81            | Growth in connection |
| 2000 | 0.20            | Weak      | 2010 | 0.37            | Weak      |
| 2001 | 0.58            | Weak      | 2011 | 0.59            | Weak      |
| 2002 | 1.11            | Growth in connection | 2012 | 0.55            | Weak      |
| 2003 | 0.07            | Weak      | 2013 | -0.67           | Strong    |
| 2004 | 1.78            | Extended negative | 2014 | 0.45            | Weak      |
| 2005 | 0.90            | Growth in connection | 2015 | 0.91            | Growth in connection |
| 2006 | 0.47            | Weak      | 2016 | 0.15            | Weak      |
| 2007 | 0.73            | Weak      |

As shown in Table 1 transportation Beijing-Tianjin-Hebei region economic growth and carbon emissions decoupling state presented four types: strong decoupling, the weak connection decoupling, growth and expansion of negative decoupling, but the sample interval of 19 years with 12 years are shown as decoupling state secondary or weak decoupling, explain decouple the overall situation is good, but has not yet reached the ideal state of decoupling[4]. The year index value of weak decoupling is mostly below 1.2, indicating that the overall growth rate of carbon emissions in The Beijing-Tianjin-Hebei region is slightly lower than or equal to the economic growth rate of the transportation industry.

From 1998 to 2001, the decoupling between economic growth and carbon emissions in The Beijing-Tianjin-Hebei region remained in a state of "weak decoupling", that is, carbon emissions increased with economic growth, but the growth rate of carbon emissions was smaller than that of transportation economy. Combined with Figure 2, it can be seen that the weak decoupling in these years is mainly due to the energy saving elasticity is less than 1, and the growth rate of energy consumption is less than that of the industry.

From 2002 to 2009, the state decoupling, appeared intermittent connection "growth" and "expansion negative decoupling", may be due to after China joined the WTO in 2002, the international economic development environment is good, the domestic increase in the number of infrastructure projects, involving the energy industry and energy consumption and CO2 emissions to accelerate; Then in 2008, due to the economic crisis and other factors, the economic growth slowed down, resulting in the negative decoupling of expansion. The data content shows that the CO2 and GTO values in Beijing-Tianjin-Hebei region are obviously increased, but the increase range of CO2 is higher than that of GTO.

After 2010, the decoupling state returned to the "weak decoupling" state, and the data content reflects the average growth of all data, and the trend is getting better. In 2012, there was a strong decoupling. As can be seen from Figure 1, the energy consumption of the three provinces and cities in Beijing, Tianjin and Hebei also decreased, indicating that the national macro low-carbon emission reduction policy played a role in the region, resulting in a reduction in energy use and a reduction in the rate of carbon dioxide emission. However, in subsequent years, the decoupling state returned to the state of weak decoupling or even growth connection, indicating that the energy use structure of the industry was still not reasonable and the problem had not been fundamentally improved[2].
4. Conclusion
This paper estimates the carbon emissions of the transportation industry in the Beijing-Tianjin-Hebei region from 1998 to 2017, and delinks the economic growth of the overall transportation industry and carbon emissions in the region based on the Tapio decoupling method. The carbon emission calculation results show that the total carbon emission of the transportation industry in the Beijing-Tianjin-Hebei region shows a rising trend within the study area. The carbon emission of Tianjin is relatively small and grows slowly, and the carbon emission base of Beijing and Hebei province is large and rising continuously.

The calculation of decoupling elasticity shows that the overall fluctuation trend of energy saving elasticity, emission reduction elasticity and decoupling elasticity is basically the same before 2009. Since 2010, the dynamic evolution pattern of decoupling elasticity of energy consumption and carbon emissions from transportation is basically the same, while the change of energy consumption emission reduction elasticity from transportation carbon emissions is opposite to the former two, and has little impact on decoupling elasticity[6]. The results show that the decoupling of transport carbon emissions from economic growth is mainly determined by the energy conservation elasticity of the transport sector, namely the utilization rate of transport energy, while the contribution of carbon emission reduction technologies corresponding to the elasticity of emission reduction to transport carbon emission has not yet been revealed.

The decoupling state shows that in most years within the research range, the Beijing-Tianjin-Hebei region as a whole presents a weak decoupling state, but in some years there is a strong decoupling, negative decoupling of expansion and growth connection. With the introduction and implementation of policies and measures related to energy conservation and emission reduction under the 11th Five-Year Plan, the decoupling of economic growth in the Beijing-Tianjin-Hebei region's transportation industry and carbon emissions has been improved since 2002[3]. However, decoupling has further returned to a state of weak decoupling and connected growth, indicating that the economic growth and carbon emissions of the transportation industry have not truly decoupled and the emission reduction situation is not optimistic. In the future, it is still necessary to continue to optimize the industrial structure and energy structure, improve the efficiency of transportation and energy utilization, and stick to the path of low-carbon transformation and development.

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