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DIFFERENCES IN CARBON EMISSION LEVELS AND INFLUENCING FACTORS IN THE LOGISTICS INDUSTRY OF BEIJING-TIANJIN-HEBEI REGION

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Abstract

As one of China's fastest growing regions, Beijing–Tianjin–Hebei (B-T-H), which contains one of the most intensive logistics networks in China, developed rapidly from 2005 to 2016. However, such growth also led to increases in energy consumption and carbon emissions. From 2005 to 2011, the growth rate of logistics carbon emissions in the B-T-H was maintained at 8%–10%. Subsequently, owing to policies and technological progress related to energy saving and emission reduction, a positive decrease in carbon emissions was observed. The statistical research revealed that the absolute difference in the logistics carbon emission level in B-T-H fluctuated greatly, the level of logistics carbon emissions was unbalanced. Use of the logarithmic mean Divisia index decomposition method revealed that the industrial scale and population scale were promoting factors of logistics carbon emissions in B-T-H, whereas energy intensity was the main inhibiting factor. The effect of the energy structure was not significant. Differences in the influencing factors of the three B-T-H areas were observed. Some suggestions are proposed: The population of B-T-H should be strictly controlled, energy intensity should be reduced, the energy structure and traffic structure should be adjusted, and a cooperation mechanism should be established.

Key words: Beijing-Tianjin-Hebei, carbon emission, energy consumption, logistics industry, logarithmic mean divisia index

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1. Introduction

Carbon emissions are a bottleneck that restricts global economic and social development (Adom et al., 2012; Wang, 2015). After 40 years of reform and opening alongside the rapid development of China's economy, resource and environmental problems are increasingly prominent. China became the world's largest carbon dioxide emitter and energy consumer in 2011, whose total energy consumption was 4.36 billion tons of standard coal and carbon dioxide emissions reached 10.21 billion tons in 2016 (Xu et al, 2019). China regards energy conservation, emission reduction, and low-carbon development as key national strategies and has promised to achieve carbon dioxide emission reduction per unit of gross domestic product (GDP) of 40%–45% by 2020 and 60%–65% by 2030 compared with the 2005 level (12.26 tons of standard coal per 10,000 yuan RMB) (Lin and Tan, 2017; Sun et al., 2016). Owing to the negative externality of carbon dioxide emissions, neighboring cities are not immune to output from surrounding areas. Cooperative emission reduction is regarded as an effective means of emission reduction. The logistics industry in China has also developed rapidly in recent times (Qi et al, 2020). However, the logistics industry is a high energy consumer and carbon emitter (Dai and Gao, 2016), and thus it is a key target for energy conservation and emission reduction. Consequently, how to effectively promote low-carbon

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development in the logistics industry is a major topic of interest in current research.

Beijing–Tianjin–Hebei (B-T-H) is China's new growth pole, following on from the Yangtze River Delta and Pearl River Delta (Yang, 2015). This region is also one of the most active and densely populated regions in China. The logistics industry in B-T-H has developed rapidly in recent years and plays a key role in promoting regional economic development; however, it is also responsible for rising energy consumption and carbon emissions. Coordinated development in B-T-H has become a national strategy, where breakthroughs are first required in transportation integration, ecological environmental protection, and industrial transference (Wu et al., 2017). To achieve the 2020 emission reduction target, China must reduce its regional logistics carbon emissions and improve its logistics efficiency. B-T-H includes the municipalities of Beijing and Tianjin, which are under the direct control of the central government, as well as Hebei Province; consequently, each region differs in terms of its economic development, population distribution, and transportation and logistics network. Therefore, when attempting to solve the carbon emission problem in the B-T-H logistics industry, regional spatial differences and factors influencing carbon emissions must be comprehensively considered to provide a policy basis for coordinated emission reduction in regional logistics.

Taken as an emerging metropolitan area in China, the research for the carbon emission levels and driving factors in logistics industry in B-T-H region will be representative. The present study aimed to answer the following questions: (1) What is the developmental status of the B-T-H logistics industry? (2) What are the characteristics of the energy consumption structure and carbon emissions in the B-T-H logistics industry? (3) Do carbon emission levels vary throughout the B-T-H logistics industry? (4) What are the factors that influence carbon emissions in the B-T-H logistics industry?

The remainder of this paper is organized as follows: Section 2 contains a review of studies on energy consumption and logistics carbon emissions in China as a whole and in B-T-H. Section 3 analyzes the developmental status of the logistics industry in B-T-H and describes the methodology, data, and analysis of carbon emissions due to energy consumption. Section 4 analyzes the influencing factors of carbon emissions in B-T-H. Finally, conclusions and a summary of this study are provided in Section 5. This paper offers theoretical support for promoting carbon emission reduction and coordinated development in the B-T-H logistics industry.

2. Literature review

Carbon emissions are a global concern; many studies have focused on reducing carbon emissions worldwide. Akadiri et al. (2019) pointed out that in the 21st century how to balance the environmental degradation and sustainable economic growth was a major challenge. With the rapid development of China's economy and B-T-H becoming China's new growth pole, study of the economic development, environment, and carbon emissions in this region has become a popular research topic (Xu et al, 2019).

Based on the"2006 IPCC Guidelines for National Greenhouse Gas Inventories", which covers carbon accounting methods, Wu and Zhao (2014) calculated the carbon dioxide emissions, emission intensity, per-capita emissions, and emissions per unit area in B-T-H in 2000–2011 and analyzed energy consumption, carbon emissions, and economic growth in the region from the perspectives of trend changes, consumption structures, correlation, and spatial distribution. Feng and Li (2017) selected 13 cities in B-T-H as their research sample and focused on the carbon dioxide emission efficiency and reduction potential of each of the three areas. Yan (2016) constructed a multiregional input–output structural decomposition analysis model to estimate carbon footprint trends in B-T-H and their drivers. Yan and Yin (2017) used a generalized Divisia index method to decompose carbon emissions into weighted contributions of eight driving factors from 2006 to 2015 in B-T-H. Zhao et al. (2018) analyzed CO2 emissions in B-T-H during 2000−2014 from temporal and spatial perspectives and identify the key driving forces of CO2 emissions in B-T-H.

Numerous studies related to lowering carbon emission levels in the transportation sector have been conducted. Achour and Belloumi (2016) applied the LMDI method to identify influencing factors and measure each factor's contribution to energy consumption in the transportation sector in Tunisia from 1985 to 2014; the study's key findings were that economic output, transportation intensity, population scale, and transportation structure were the most influential factors contributing to the growth of carbon emissions, whereas the effect of energy intensity contributed markedly to decreasing emissions. Lu et al., (2007) studied carbon emissions from highway transport vehicles in Germany, Japan, and South Korea from 1990 to 2002; the observed influencing factors included changes in the emission coefficient, fuel structure, population scale, and economic scale. Timilsina and Shrestha (2009) investigated carbon emissions in the transportation sectors of several Asian countries from 1980 to 2005 and found that economic growth, population size, and energy intensity were the main factors leading to increasing carbon emissions. Tapio (2005) proposed the decoupling elasticity coefficient and explored the decoupling of economic growth and transport volume in Finland from 1970 to 2001; other authors used the LMDI decomposition method to analyze the factors influencing carbon emission changes in the transportation industry (Dai and Gao, 2016). Qian and Gao (2018) measured carbon emissions due to traffic and transportation energy consumption in B-T-H from 2000 to 2013 and established a carbon driving model based on the STIRPAT model; the results revealed that per-capita GDP, energy intensity, the proportion of tertiary industry, and public transportation were the most influential factors driving carbon emissions.

Transportation is a function of logistics, which is a complex service industry that integrates the transportation, warehousing, freight-forwarding, and information industries. Taking China's logistics industry as an example, previous studies have focuses on three main aspects, described as follows. First, analysis of the overall amount of carbon emissions in China's logistics industry. Wang and Liu (2018) measured carbon emissions based on an input–output table of China's logistics industry from 1997 to 2014; the researchers also used the LMDL method to analyze the factors influencing carbon emissions. Zhang and Li (2018) analyzed the characteristics of energy consumption, carbon emissions, and logistics development in China from 2003 to 2012. Second, analysis of regional logistics carbon emissions. Xiao et al. (2015) employed the degree of regional logistics energy utilization and the spatial distribution of carbon emissions as two indicators of green logistics to investigate regional differences and changes in spatiotemporal logistics energy efficiency. Jin et al. (2016) measured carbon emissions in China during 1997–2012 to analyze the evolution process of regional logistics carbon emission intensity. Third, analysis of logistics carbon emissions in B-T-H. Li (2013) designed an evaluation system for logistics carbon emissions using B-T-H as an example and conducted an empirical analysis by using the fuzzy matter element method and data from 2004 to 2010. Quan et al. (2016) first measured carbon emissions in the logistics industry in B-T-H and subsequently investigated the driving factors of carbon emissions in said industry from 1998 to 2012 by using the LMDI decomposition model; the decoupling effect was also analyzed.

3. Analysis of current logistics carbon emissions in B-T-H

3.1. Developmental status of the B-T-H logistics industry

This paper defines the logistics industry as comprising the transportation, warehousing, and postal service industries. Compared with those in developed countries, the logistics industry in China developed late, and its infrastructure is outdated. However, with the rapid development of China's economy in recent years, the demand for logistics is increasing. B-T-H is the area with perhaps the greatest potential for economic development in China, and the logistics industry in this area has developed rapidly over the preceding decade under the guidance of relevant policies.

The added value of the logistics industry in Beijing increased from 40.3 billion RMB in 2005 to 106.1 billion RMB in 2016, yielding an average annual growth rate of 9.19%. The added value of the logistics industry in Tianjin increased from 27.7 billion RMB to 72.5 billion RMB during the same period, yielding an average annual growth rate of 9.13%. The average annual growth rate of Hebei Province was 10.5% during this period. The added value of the logistics industry in B-T-H as a whole grew at an average annual rate of 9.9%. The growth rate can be separated into the periods before and after 2011; that before 2011 (inclusive) was 15.48%, whereas that after 2011 was only 3.5%.

The amount of fixed asset investments reflects the infrastructure of the logistics industry, which in B-T-H exhibited an overall growth trend from 2005 to 2016, with especially rapid growth before 2013, accounting for approximately 9% of the total amount of national investment; a peak of 10.8% was observed in 2007. In recent years, with the increasingly improved infrastructure of the B-T-H logistics industry, its proportion of national investment has decreased. However, fixed asset investment in logistics has increased annually in Hebei Province, accounting for 58.3% of that in B-T-H in 2016, up from 39.9% in 2008. This indicates that Hebei Province increased its construction of regional logistics based on the implementation of B-T-H integration.

Alongside the rapid development of the regional economy, the freight volume of B-T-H exhibited an overall growth trend, reaching a peak in 2012. However, B-T-H's share of the national total fell from 8.6% in 2005 to 6.4% in 2016. The total amount of freight in Beijing fell most markedly, mainly because of the development of the national economy and internal industrial structure. Development of the national economy (GDP growth) drives freight volume growth as a whole, and freight volume per unit of GDP is positively correlated with primary industry, strongly positively correlated with secondary industry, and negatively correlated with tertiary industry (Wang, 2012). Adjustment of the industrial structure (the proportions of the primary and secondary industries decrease, and that of the tertiary industry increases) causes a continuous decline in freight volume per unit of GDP that offsets the pulling effect of the national economy on freight volume. The result is that the growth rate of freight volume is lower than that of GDP; this is a characteristic of freight volume during economic structural adjustment. From 2005 to 2012, the GDP of B-T-H maintained a high growth rate in the double digits, which led to the growth of freight volume. In recent years, the structure of China's economy has changed and the growth rate of freight volume has decreased. In 2016, the structure of the three industries (primary, secondary, tertiary) in B-T-H was 5.2% : 37.3% : 57.5%, whereas nationally the proportion was 8.6% : 39.8% : 51.6%. Thus, the B-T-H proportion was evidently higher than the national proportion. In Beijing in 2016, the proportion of the tertiary industry reached 80.2%, whereas that of the secondary industry was only 19.3%, and freight volume accounted for only 7.3% of the total volume in B-T-H. From 2005 to 2016 in Hebei Province, the proportion of the secondary industry fell by 5.2%, whereas that of the tertiary industry increased by 8.2%; during the same period, the proportion of the national secondary industry fell from 47% to 39.8%, whereas that of the tertiary industry increased from 41.3% to 51.6%. Currently, Hebei Province remains dominated by heavy industries such as steel and cement; this has boosted the share of freight traffic in B-T-H to 75%.

3.2. Characteristics of energy consumption and carbon emissions in the B-T-H logistics industry

3.2.1. Methodology and data

According to the IPCC method of greenhouse gas emission inventories, carbon emissions can be estimated via the Eq. (1):

$$C = \sum_{i=1}^{n} E_i F_i K_i \quad (1)$$

where: C denotes the total carbon emissions of the logistics sector; E_i is the consumption of the *i*th fuel; F_i is the conversion coefficient of standard coal of the *i*th fuel, and K_i is the carbon emission factor of the *i*th fuel. *i*=1,2,…..,8, respectively represent raw coal; gasoline; kerosene; diesel; fuel oil; liquefied petroleum gas; natural gas and electricity. In order to ensure the comparability of the data, all fuels should be converted into standard coal. In the calculation of carbon emissions, only the terminal consumption of energy is calculated, and the loss in the process of processing and conversion, transportation, distribution and storage is not calculated. We know that electricity cannot directly generate carbon emissions, so the carbon emission factor of electricity is zero. Energy consumption data E_i in this paper comes from Beijing energy balance sheet, Tianjin energy balance sheet and Hebei energy balance sheet in China Energy Statistical Yearbook from 2001 to 2017.Energy conversion standard coal reference coefficient F_i comes from China Energy Statistical Yearbook in 2016. The carbon emission factor K_i data were referenced from the 2006 *IPCC National Greenhouse Gas Inventory Guidelines* and the research results of Ke et al. (2015). The conversion coefficient of standard coal references is found in Table 1.

3.2.2. Characteristics of the level and structure of logistics energy consumption in B-T-H

As shown in Fig. 1, Energy consumption has risen in B-T-H in recent times. The main sources of energy consumption in the logistics industry are raw coal, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas, and electricity. However, because of variables such as geographical location and infrastructure, energy consumption can differ by region.

The main sources of logistics energy consumption in Beijing are kerosene, diesel, gasoline, electricity, natural gas, and raw coal; kerosene is the highest contributor (Yang and Gao, 2016). After 2009, the contribution of kerosene increased annually, reflecting the development of air transport. With the impending opening of Beijing Daxing International Airport in 2019, Beijing's aviation logistics will likely begin to develop more quickly. With the gradual increase of new energy vehicles powered by electricity and natural gas, the consumption of diesel and gasoline has decreased in recent years, and the total consumption of raw coal has been falling since 2005.

The main sources of logistics energy consumption in Tianjin are diesel, fuel oil, kerosene, gasoline, electricity, raw coal, and natural gas (Hong and Lv, 2020). The Tianjin waterway transport industry is relatively well developed, and thus diesel is the highest contributor to energy consumption in Tianjin, with fuel oil also making a considerable contribution.

However, after 2012, kerosene consumption increased and fuel oil consumption decreased; although water transport saves on cost, it is not time efficient, and businesses began to migrate to air transport. Data show that the highway freight volume of Tianjin gradually decreased after reaching a peak in 2012; in addition, gasoline consumption fell sharply after 2012, while natural gas consumption increased markedly, and electricity consumption also increased annually.

The main sources of logistics energy consumption in Hebei Province are diesel oil, gasoline, electricity, natural gas, raw coal, and kerosene. Hebei is a major heavy chemical industrial base in China. The many ships, items of engineering machinery, and trucks that pass through the province have led to high diesel consumption that is rising further. Due to electrified railway mileage increasing and the use of new energy-hungry vehicles, electricity and gas consumption are growing, with raw coal consumption exhibiting a downward trend. Moreover, alongside the continued development of aviation transportation, kerosene consumption has exhibited marked growth since 2013.

Table 1. Conversion coefficients of standard coal and carbon emissions of diverse fuels.

Unit	*Raw coal*	*Gasoline*	*Kerosene*	*Diesel oil*	*Fuel oil*	*Liquefied petroleum gas*	*Natural gas*	*Electricity*
F_i (tce/t)	0.7143	1.4714	1.4714	1.4571	1.4286	1.7413	13.30 (tce/104m^3)	1.229 (tce/104kWh)
K_i (t/tce)	0.7559	0.5538	0.5714	0.5921	0.6158	0.5042	0.4483	0

'tce' denotes ton of standard coal equivalent.

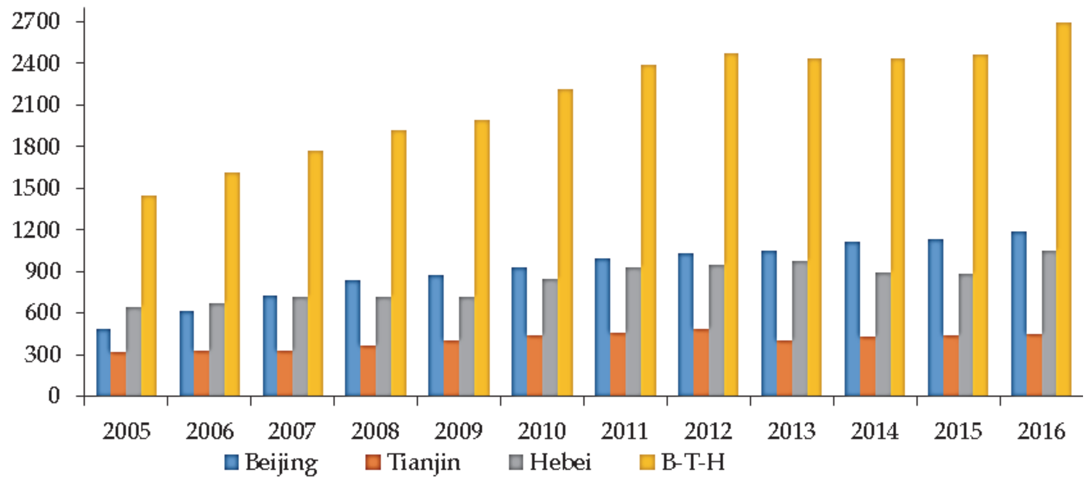

Fig. 1. Energy consumption of logistics industry in B-T-H

3.2.3 Characteristics of and differences in logistics carbon emissions in B-T-H

1. Total carbon emissions and their growth rate in the B-T-H logistics industry

From 2005 to 2016, carbon emissions in the logistics industry in B-T-H exhibited an overall growth trend; among the various components, logistics carbon emissions in Beijing maintained a rising trend after reaching a peak in 2012, and logistics carbon emissions in Tianjin have declined slightly in recent years. Logistics carbon emissions in Hebei Province fell after reaching a peak in 2013 but increased markedly in 2016. From 2005 to 2007, logistics carbon emissions in B-T-H maintained a growth rate of 8%–10%.

Following the 2008 financial crisis, the growth rate logistics carbon emissions decreased markedly in 2009. However, during 2010–2011, the development of the logistics industry resulted in high carbon emissions. From 2012 to 2015, owing to policies and technological progress related to energy saving and emission reduction, a negative increase in carbon emissions was observed. However, a marked increase was observed in 2016, mainly because of the increase in logistics carbon emissions in Hebei Province.

2. Differences in logistics carbon emission levels in B-T-H

Carbon productivity (y) refers to the output level of unit carbon emissions, which is measured by the ratio of added value of the logistics industry to carbon emissions. The lower the carbon productivity is, the lower the logistics output is per unit of carbon dioxide and the higher the carbon emission level (Eq. 2).

$$y = Y / C \tag{2}$$

C represents the calculated total logistics carbon emission, unit: ten thousand tons; Y is the added value of logistics industry, in order to eliminate the influence of price factor, the nominal value of the added value of logistics industry is adjusted to the actual added value of constant price in 2005, unit: billion, data source: China Statistical Yearbook 2017.

Fig. 2 and Fig. 3 shows that Beijing, Tianjin, and Hebei differed in terms of carbon productivity, which ranged from high in Hebei to low in Beijing, with Tianjin in between. The carbon productivity of B-T-H exhibited an overall upward trend, and the carbon emission level gradually decreased.

To investigate variations in regional logistics carbon emissions, this study employed the standard deviation and range as indicators to analyze absolute differences among regional logistics carbon emission levels. The range reflects the discrete range of differences in regional logistics carbon emissions; the wider the range, the greater is the difference between two regions. The formula is expressed as follows (Eq. 3):

$$\eta = X_{max} - X_{min} \tag{3}$$

where: η is extremum, and X represents the carbon productivity indicators of B-T-H.

The standard deviation reflects the absolute dispersion level of regional carbon emission differences; the higher the standard deviation is, the greater is the dispersion degree of logistics carbon emissions in different regions (Eq. 4).

$$\varsigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n}} \tag{4}$$

Fig. 4 shows that the absolute difference among logistics carbon emission levels in B-T-H fluctuated greatly and was unstable. The variation trend of the range and standard deviation was consistent, exhibiting an overall upward trend. The discrepancy of carbon productivity between Beijing, Tianjin, and Hebei has increased in recent years, and the level of logistics carbon emissions is unbalanced.

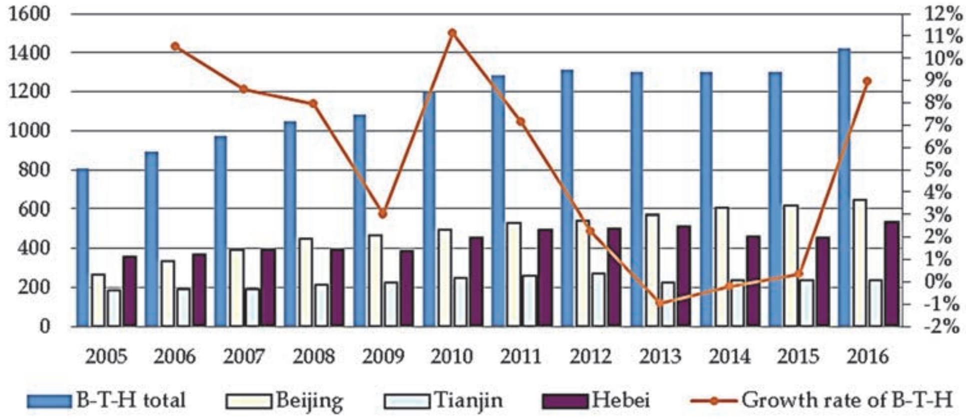

Fig. 2. Total and growth rate of logistics carbon emission in B-T-H from 2005 to 2016

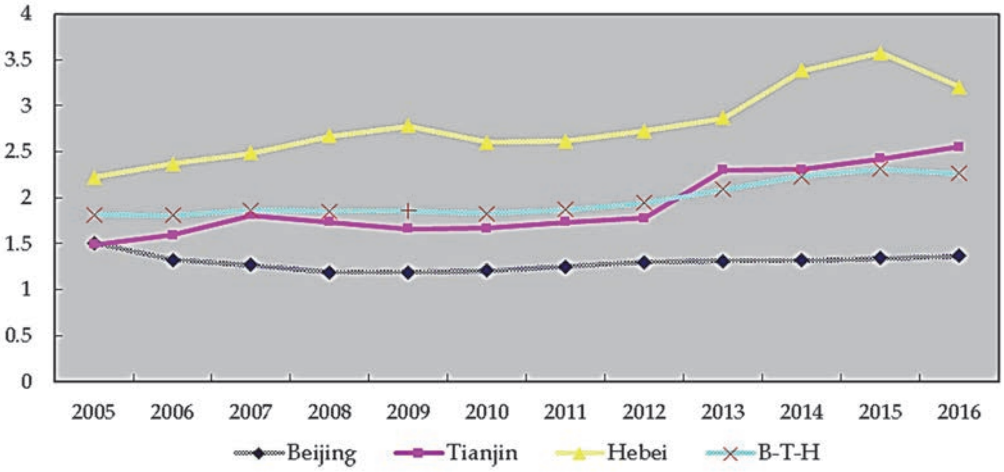

Fig. 3. Carbon productivity in the B-T-H from 2005 to 2016

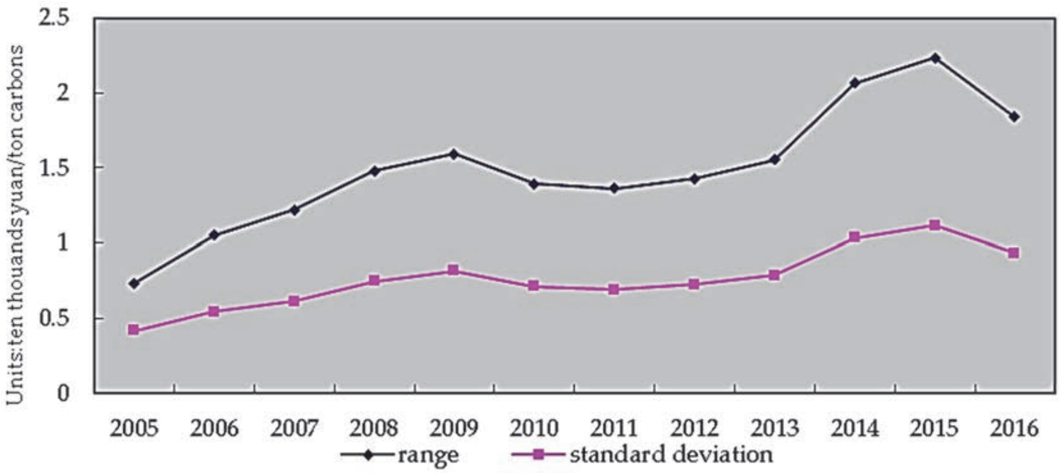

Fig. 4. Carbon productivity in the B-T-H from 2005 to 2016

4. Influencing factors of logistics carbon emissions in B-T-H

4.1. Model building and data sources

To investigate the driving factors of logistics carbon emissions in B-T-H, the factors of carbon emissions must be further analyzed. According to related studies, the most widely used decomposition methods to analyze influencing factors are structural decomposition and exponential decomposition. However, because of difficulty in data acquisition, the structural decomposition method is rarely applied. The exponential decomposition method, also known as index decomposition analysis, is easy to implement and suitable for time-series analysis. Decomposition models commonly used for exponential decomposition include the Laspeyres decomposition model and Divisia decomposition model, and the LMDI decomposition method is one of the primary research methods used to examine influencing factors of carbon emissions (Ang, 2004). The basic purpose of the LMDI method is decomposition of the changes in a target variable into a combination of several influencing factors. Such decomposition is performed so that each factor's degree of influence - that is, its contribution rat - can be identified. The LMDI method does not produce residuals, and thus it is a relatively effective decomposition method. This study used the LMDI method to analyze the influencing factors of carbon emissions in the B-T-H logistics industry (Guo, 2010). The following subsections describe how carbon emissions in the logistics industry were decomposed (Eq. 5).

$$C=\sum_i C_i^t=\sum_i \frac{C_i^t}{E_i^t}\times\frac{E_i^t}{E^t}\times\frac{E^t}{Y^t}\times\frac{Y^t}{P^t}\times P^t \quad (5)$$

In Eq. (5): C stands for logistics carbon emission, t - time, i - energy type, C_i - carbon emission of energy type i, E_i - the energy consumption of type i, E - total logistics energy consumption, Y - logistics output value, P - regional population. Then the formula can be written as Eq. (6):

$$C=\sum_i (CEF_i^t\times ETE_i^t\times EYS^t\times YPT^t\times PTS^t) \quad (6)$$

$CET = C_i/E_i$ represents the carbon emission generated by unit energy consumption, namely the carbon emission coefficient; $ETE_i = E_i/E$ represents the proportion of energy of type i in logistics energy consumption, namely energy structure; $EYS^t = E^t/Y^t$ represents the energy consumption per unit of added value of logistics industry in period t, namely energy intensity; $YPT^t = Y^t/P^t$ represents per capita GDP of logistics, namely industrial scale effect; $PTS = P$ represents the number of population in a region, namely the population size effect.

As can be clearly seen from (6), the carbon emissions in the logistics sector are divided into five separate factors, namely (1) the carbon emission coefficient factor. (2) energy structure factor (3) energy intensity factor, (4) industrial scale factor, (5) the population size factor. The difference in the levels of carbon emissions in the logistics sector between the base period and the t period is called the cumulative effects ΔC. Also, ΔC refers to the total changes in carbon emissions, and ΔC consists of 5 parts, namely (1) carbon emission coefficient effect ΔCCEF; (2) energy structure effect ΔCETE ;(3) energy intensity effect ΔCEYS ;(4) industrial scale effect ΔCYPT and (5) population size effect ΔCPTS. These represent the contribution of each factor to the changes in logistics carbon emissions, D represent the contribution rate of each factor to the changes in logistics carbon emissions, which is (Eqs. (7-14):

$$\Delta C=C^t-C^0=\Delta C_{CEF}+\Delta C_{ETE}+\Delta C_{EYS}+\Delta C_{YPT}+\Delta C_{PTS} \quad (7)$$

$$\Delta C_{CEF}=\sum_i W_i\times\ln\frac{CEF_i^t}{CEF_i^0} \qquad D_{CEF}=\Delta C_{CEF}/\Delta C \quad (8)$$

$$\Delta C_{ETE}=\sum_i W_i\times\ln\frac{ETE_i^t}{ETE_i^0} \qquad D_{ETE}=\Delta C_{ETE}/\Delta C \quad (9)$$

$$\Delta C_{EYS}=\sum_i W_i\times\ln\frac{EYS_i^t}{EYS_i^0} \qquad D_{EYS}=\Delta C_{EYS}/\Delta C \quad (10)$$

$$\Delta C_{YTP}=\sum_i W_i\times\ln\frac{YTP_i^t}{YTP_i^0} \qquad D_{YTP}=\Delta C_{YTP}/\Delta C \quad (11)$$

$$\Delta C_{PTS}=\sum_i W_i\times\ln\frac{PTS_i^t}{PTS_i^0} \qquad D_{PTS}=\Delta C_{PTS}/\Delta C \quad (12)$$

$$W_i=\frac{C_i^t-C_i^0}{\ln(C_i^t-C_i^0)} \quad (13)$$

$$D=D_{CEF}+D_{ETE}+D_{EYS}+D_{YTP}+D_{PTS}=1 \quad (14)$$

Generally, the carbon emission coefficients of all types of fossil fuels are fixed, so $\Delta C_{CEF} = 0$, $\Delta D_{CEF} = 0$, Therefore, the factors affecting logistics in BTH are mainly the energy structure, energy intensity industrial scale and population size. The energy data comes from the energy balance table of China Energy Statistics Yearbook from 2006 to 2016 (Fig. 4). The added value of logistics industry and population data come from China Statistical Yearbook of national bureau of statistics. In order to eliminate the influence of price factor, the nominal value of added value of logistics industry is adjusted to the actual added value of constant price in 2005.

4.2. Influencing factors of logistics carbon emissions in Beijing

Figs. 5-7 shows that from 2006 to 2016, carbon emissions in the logistics industry of Beijing increased; the industrial scale and population scale were the main influencing factors, whereas the energy structure had little influence (Yang and Gao, 2016). Before 2008, energy intensity played a promotional role; this was because alongside the development of the national economy, the development of the logistics industry accelerated, causing high energy consumption and high emission levels. In recent years, the development of low-carbon logistics has accelerated, more clean energy has been developed and introduced, and energy efficiency has increased. Since 2011, energy intensity has played a role in restraining carbon emissions. The contribution of the industrial scale increases annually, and that of population size has been consistently increasing; however, since 2014, the increment of the population in Beijing has decreased, and the contribution of population size has stabilized.

4.3. Influencing factors of logistics carbon emissions in Tianjin

Logistics carbon emissions increased in Tianjin from 2006 to 2016; the contributions of energy intensity and the industrial scale were significant (Hong and Lv, 2020), whereas the impact of the energy structure was not. Energy intensity has long played a role in restraining carbon emissions, and the industrial scale has long influenced carbon emissions. After reaching a peak in 2012, logistics carbon emissions in Tianjin fell slightly. The population of Tianjin continues to grow, and population size has played a role in promoting carbon emissions. In recent years, population growth in Tianjin has slowed, and the contribution of population size has decreased.

4.4. Influencing factors of logistics carbon emissions in Hebei

Among the influencing factors of logistics carbon emissions in Hebei Province, the impact of the energy structure was not significant, whereas energy intensity and the industrial scale contributed greatly. Energy intensity has long played a role in restraining carbon emissions, and the industrial scale is the primary cause of increasing emissions. Population size plays a promotional role, but its effect is not significant compared with that of the industrial scale.

On the whole, the logistics industry in B-T-H has developed rapidly in recent years. The infrastructure has improved, and transportation has gone from strength to strength. Although the scale of the logistics industry may fluctuate as the integration of B-T-H accelerates, the overall contribution of carbon emissions will likely continue to rise.

4.5. Influence of the energy structure on logistics carbon emissions in B-T-H

As what mentioned before, the influence of the energy structure on carbon emissions is not significant; however, further analysis is required to confirm this. In Table 2, we see that the energy structure inhibited carbon emissions from 2007 to 2012 in Beijing but promoted them in all other years. Tianjin was divided into three stages, namely 2006–2009, 2010–2012, and 2013–2016, during which emissions were restrained, promoted, and restrained by the energy structure, respectively. In 2006, 2008, and 2009, the energy structure inhibited carbon emissions in Hebei Province. In all other years, carbon emissions were promoted, with the range of fluctuation being relatively wide.

The carbon emission coefficient of each energy source is different, and thus when the type and proportion of energy consumed in logistics activities change, carbon emissions are promoted or inhibited. The proportion of kerosene in Beijing has increased annually since 2009, exceeding the declines in gasoline and raw coal, both of which promote carbon emissions. Since 2012, the consumption of gasoline in Tianjin has dropped significantly, and the use of natural gas has increased significantly.

The use of electricity has increased annually, and this has exerted an overall inhibitory effect on carbon emissions. With the exception of 2008 and 2009, diesel and kerosene consumption in Hebei Province grew during the study period, and the use of clean energy accounted for a low proportion of the total consumption; thus, the energy structure played a role in promoting carbon emissions.

5. Conclusions and policy implications

5.1. Conclusions

To achieve its 2020 emission reduction target, China must reduce its regional logistics carbon emissions and improve its logistics efficiency. This study employed logistics carbon emissions in B-T-H as its research target to analyze the developmental status of the B-T-H logistics industry and differences among carbon emission levels and their influencing factors. The main research findings are summarized as follows.

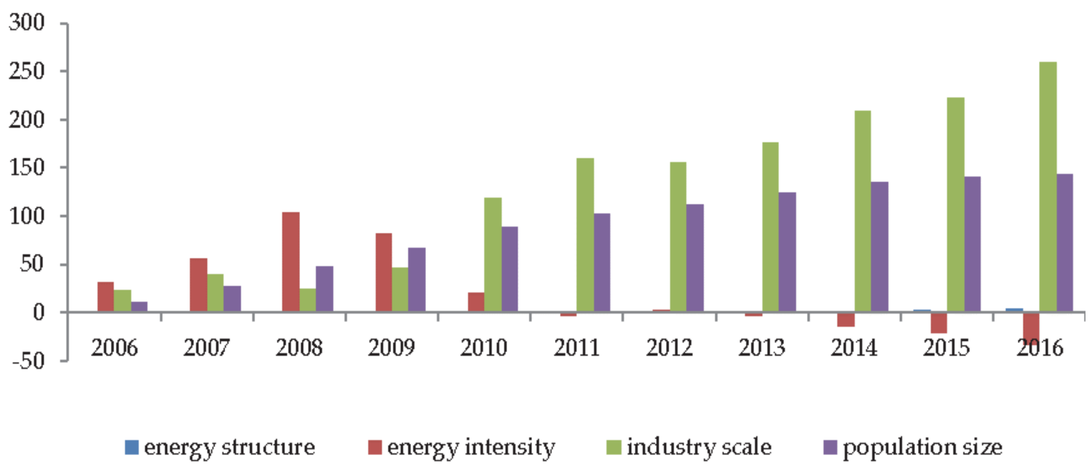

Fig. 5. Influencing factors of logistics carbon emission in Beijing from 2006 to 2016

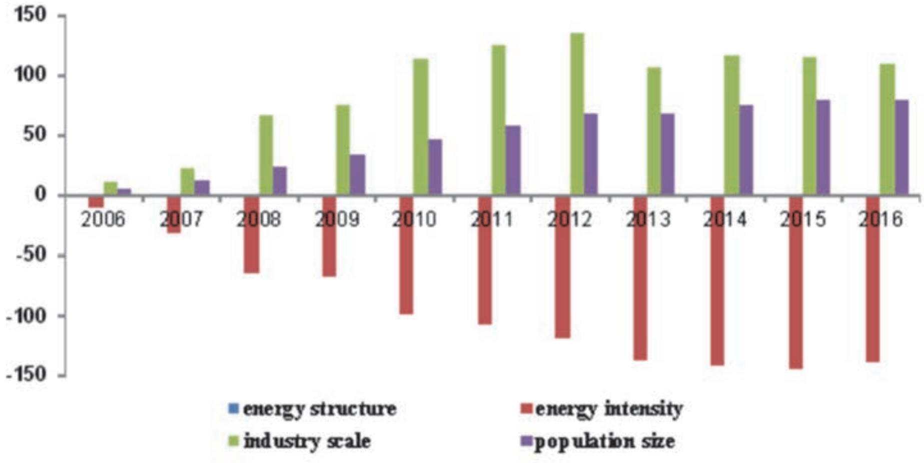

Fig. 6. Influencing factors of logistics carbon emission in Tianjin from 2006 to 2016

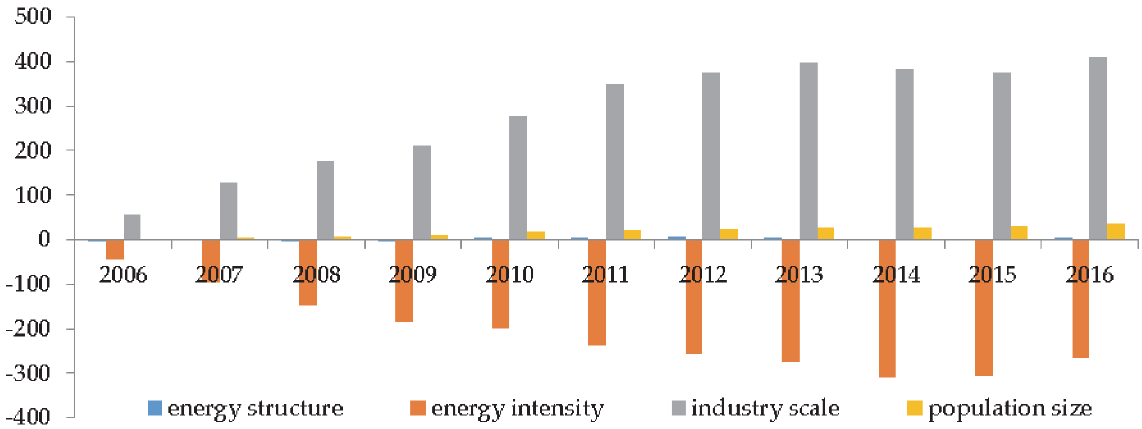

Fig. 7. Influencing factors of logistics carbon emission in Hebe from 2006 to 2016

Table 2. Influence of the energy structure on logistics carbon emissions in B-T-H

Year	*Energy structure effect in Beijing*		*Energy structure effect in Tianjin*		*Energy structure effect in Hebei*	
	ΔCETE	*DETE*	*ΔCETE*	*DETE*	*ΔCETE*	*DETE*
2006	0.05	0.0007	-0.10	-0.0202	-2.24	-0.1996
2007	-0.04	-0.0003	-0.77	-0.3830	0.93	0.0263
2008	0.44	0.0025	-0.28	-0.0114	-0.82	-0.0236
2009	0.38	0.0019	-0.52	-0.0126	-1.88	-0.0580
2010	0.63	0.0027	0.50	0.0080	3.14	0.0321
2011	0.78	0.0030	0.60	0.0079	4.96	0.0354
2012	-0.42	-0.0016	0.01	0.0001	5.95	0.0401
2013	1.44	0.0048	-0.76	-0.0209	5.24	0.0339
2014	1.16	0.0035	-0.41	-0.0082	2.48	0.0237
2015	2.83	0.0082	-0.86	-0.0180	1.14	0.0117
2016	4.43	0.0118	-0.92	-0.0185	4.47	0.0244

1. In recent years, the logistics industry in B-T-H has developed rapidly, and the added value of this industry and its fixed asset investments has increased consistently. Fixed asset Investment in Hebei increased from 39.9% in 2008 to 58.3% in 2016, demonstrating that Hebei Province has increased its construction of regional logistics bases since the implementation of B-T-H integration.

2. From 2005 to 2016, energy consumption and carbon emissions in the B-T-H logistics industry exhibited an overall upward trend. Among the individual components, carbon emissions have maintained an upward trend in Beijing, declined slightly in recent years after reaching a peak in 2012 in Tianjin, and declined after reaching a peak in 2013 before increasing significantly in 2016 in Hebei Province. From 2005 to 2007, logistics carbon emissions in B-T-H maintained a growth rate of 8%–10%. Under the influence of the financial crisis of 2008, this growth rate decreased significantly in 2009.

Following the economic recovery of 2010–2011, the development of the logistics industry produced considerable carbon emissions. From 2012 to 2015, owing to policies and technological progress related to energy saving and emission reduction, a negative increase in carbon emissions was observed. However, a significant increase was observed in 2016, mainly because of the increase in logistics carbon emissions in Hebei Province.

3. The absolute difference of logistics carbon emission levels in B-T-H fluctuated greatly and was unstable. The variation trend of the range and standard deviation was consistent, exhibiting an overall upward trend. The gap in carbon productivity between Beijing, Tianjin, and Hebei increased during the study period, and the level of logistics carbon emissions was unbalanced.

4. Use of the LMDI decomposition method revealed the following findings. The industrial scale and population scale were promotional factors of logistics carbon emissions in B-T-H, whereas energy intensity was the main inhibiting factor; the effect of the energy structure was not significant. The influencing factors differed among the three areas of B-T-H. The industrial scale and population scale were the primary influencing factors in Beijing; after 2011, energy intensity had an inhibitory effect on carbon emissions, but this effect was weaker than the corresponding effects in Tianjin and Hebei Province. Energy intensity, the industrial scale, and the population scale were the main influencing factors in Tianjin. The industrial scale and energy intensity were the main influencing factors in Hebei Province. Owing to differences in energy varieties, the energy structure continues to play a role in promoting carbon emissions in Beijing and Hebei, and thus adjustment of the energy structure in these areas is imperative.

5.2. Policy implications

Carbon emissions in the B-T-H logistics industry are a key contributor of all carbon emissions in B-T-H. Regarding the process of coordinated development in B-T-H, green development must be implemented to guide and regulate the development of low-carbon and green logistics.

5.2.1. Strict population control

Population size is positively correlated with carbon emissions; excessive population growth can lead to the production of more carbon emissions. Beijing's rapid economic development and high degree of urbanization have produced a greater traffic demand, making carbon emission regulation more difficult than in Tianjin and Hebei. Thus, strict population control in B-T-H is required, especially in Beijing and Tianjin. We suggest a coordinated development program be implemented in B-T-H to ensure that the population is appropriately dispersed and to alleviate population pressure.

5.2.2. Consistent reduction of energy consumption intensity

LMDI analysis revealed that energy intensity exerted a significant inhibitory effect on carbon emissions. High vehicle density and severe vehicle congestion greatly reduced transport efficiency, and energy intensity had a weaker inhibitory effect on carbon emissions in Beijing than in Tianjin and Hebei; therefore, energy intensity still has great potential to restrict traffic carbon emissions in Beijing. The three areas of B-T-H are recommended to implement transportation integration, increase investment in transportation infrastructure, improve driving conditions, and reduce the overall energy intensity. A logistics distribution circle may be formed to effectively connect various modes of transportation in B-T-H, improve logistics efficiency in all three areas, and make full use of the inhibitory effect of energy intensity.

5.2.3. Adjustment of the energy structure and traffic structure

The energy structure of the logistics industry in B-T-H, which is dominated by diesel and kerosene, has seen no significant improvement in recent years; however, potential for large-scale improvement remains. The contributions of kerosene and diesel to transportation energy consumption should be reduced, and use of clean energy such as natural gas, electricity, and solar energy should be increased. Although conventional diesel and petrol stations are well established, the number of filling stations and charging stations is very low; therefore, to promote use of vehicles powered by natural gas or electricity, B-T-H is recommended to improve aspects of its infrastructure, including construction of more gas filling stations and charging stations. In addition, the energy structure in B-T-H is closely related to the traffic structure. Among all available modes of transportation, aviation has the highest energy consumption per unit, followed by (from highest to lowest consumption) road, rail, and waterway transport. Due to the rapid development of e-commerce, efficiency and speed are increasingly prized in logistics, which has led to the rise of air transport in Beijing. In recent years, China's high-speed rail network has developed rapidly, and a B-T-H intercity high-speed rail service is under construction. In the future, use of intercity high-speed rail freight should be promoted.

A rational layout should be designed to link various modes of transportation that increases the combined efficiency and overall advantages of the transportation system.

5.2.4. Establishment of a cooperation mechanism to reduce logistics carbon emissions in B-T-H

- Strengthening top-level design. Regional governance can only lead to a rise in governance costs. B-T-H should strengthen coordination and cooperation, strengthen top-level design, establish a low-carbon cooperative development fund for all three areas, and increase support for energy conservation and emission reduction in the transportation and logistics industries.

- B-T-H should establish strict industrial emission reduction standards, strengthen the supervision of high-energy-consuming and high-emission agricultural and industrial diesel locomotives in Hebei Province, and formulate reasonable carbon-trading mechanisms.
- The cooperative research and development mechanism for equipment and technology in the warehousing and transportation industries of all three B-T-H areas should be strengthened. The government should encourage technological research and the development of enterprises through tax breaks, financial subsidies, and other means.
- Innovation-driven development should be strengthened and the integrated development model of the low-carbon logistics industry chain should be promoted.

Collaborative reduction depends on innovation. Therefore, B-T-H should shift from industrial structure adjustment to industrial chains upgrading. A model titled "Beijing R&D: Transformation of Achievements in Tianjin and Hebei" is being developed to drive the flow of talent, technology, and capital among regions; strengthen connection and integration among the three B-T-H areas; and promote the transformation of the regional logistics industry system to a low-carbon, high-end system.

Because of the limitations of the statistical data, only four factors, namely the industrial scale, population scale, energy intensity, and energy structure, were employed in this study as influencing factors for the growth of regional logistics carbon emissions.

Thus, factor selection in this study was not sufficiently comprehensive. With the deepening of research on regional logistics and carbon emissions, analysis of influencing factors must be improved, and indicator selection must be further refined.

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