Research on Decoupling of China's Logistics Demand and Energy Consumption Carbon Emission

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Abstract. At present, China pays more and more attention to the development of green logistics, while the logistics industry is still at the stage of extensive development, deviating from the green, low-carbon and efficient development concept. Therefore, the analysis of the characteristics of energy consumption and carbon emissions in the logistics industry has important theoretical and practical significance for the formulation of effective energy-saving and emission reduction strategies. Using the carbon emission coefficient method to calculate the logistics industry carbon emissions, and using the decoupling theory to analyze the correlation between the logistics freight volume and the logistics industry energy consumption and carbon emissions. The results show that China's logistics industry is trying to change the development mode, adapt to the impact of policy and economic environment. So as to adapt to the needs of the logistics market, logistics industry gradually transform to the complex industry.

1. Introduction
At present, China's tertiary industry is developing rapidly, and logistics has become a pillar industry to promote national economic development. Logistics industry has the characteristics of high operation cost, low production efficiency and large energy consumption, and has increasingly become an important industry focusing on carbon emission reduction in China. In October 2014, the state council issued «The medium and long-term plan for the development of logistics industry (2014-2020)», which mentioned the main principles of energy conservation, emission reduction, green environmental protection, standard improvement and efficiency improvement, and also put forward the main tasks of vigorously developing green logistics. Choosing to study the complex relationship among carbon emission, energy consumption and logistics demand in the logistics industry is of great theoretical and practical significance for effectively exploring the characteristics of energy consumption and carbon emission in the logistics industry and formulating effective energy-saving and emission reduction strategies.

2. Literature Review
In recent years, a lot of research has been done on carbon emission measurement, carbon footprint, and the relationship between carbon emission and economic growth. In 2005, Tapio [1] took the Finnish transportation industry as an example to study the decoupling relationship between carbon emissions and economic growth. Based on the OECD index model, it introduced intermediate variables and decoupling elasticity to establish Tapio decoupling elasticity model. Ma xiaojun [2] combined the
extended Kaya identity with the logarithmic average dichrood exponential decomposition method, and took the major energy consumption data of the three provinces in northeast China from 2005 to 2016 as the research object, to construct an optimized carbon emission decomposition model, and measure and decompose its carbon emission and carbon emission intensity. Wang Liping [3] measured the direct energy consumption carbon emissions of China's logistics industry from 1997 to 2014 and the implied carbon emissions based on the input-output table based on the input-output method.

The paper takes China's logistics industry as an example, builds the decoupling model based on Tapio decoupling theory, conducts a quantitative analysis of the decoupling relationship between China's logistics industry demand and energy consumption carbon emissions from 2008 to 2016, and proposes targeted energy-saving and emission reduction measures. So as to achieve the organic unity of economy, energy and environment in the low-carbon development of China's logistics industry.

3. Research Method

3.1. Logistics carbon emission measurement

The carbon emission coefficient method is used to calculate the carbon emission of the logistics industry. The calculation formula is as follows:

\[ C = \sum_{i=1}^{n} \beta_i E_i \]  

\((1)\)

\(C\) represents the carbon emissions directly related to energy consumption of the logistics industry; \(E_i\) represents the consumption of various types of energy in logistics operation; \(i\) represents the carbon emission coefficients of various energy sources, as shown in table 1.

| Fuel type        | Coal | Coke | Crude oil | Fuel oil | Gasoline | Kerosene | Diesel | Natural gas | Electric power |
|------------------|------|------|-----------|----------|----------|----------|--------|-------------|----------------|
| Fold the standard coal coefficient | 0.7143 | 0.9714 | 1.4286 | 1.4286 | 1.4714 | 1.4571 | 1.33 | 3.27 | |
| Carbon emission coefficient | 0.7559 | 0.855 | 0.5538 | 0.5857 | 0.5921 | 0.5714 | 0.6185 | 0.4483 | 0 |

3.2. Decoupling model

The Tapio decoupling model in p.Tapio [1] is introduced here, and the definitions are shown in formula (2) and formula (3).

(1) The decoupling relationship between logistics energy consumption and freight volume.

\[ D_{E-F} = \frac{(E_{t+1} - E_t)}{E_t} \frac{1}{(F_{t+1} - F_t)} / F_t \]  

\((2)\)

\(D_{E-F}\) is the decoupling index between energy consumption and freight volume of logistics industry; \(E_t\) stands for the logistics industry energy consumption at the time of \(t\); \(E_{t+1}\) stands for the logistics industry energy consumption at the time of \(t+1\); \(F_t\) stands for the logistics freight volume at the time of \(t\); \(F_{t+1}\) stands for the logistics freight at the time of \(t+1\).

(2) Logistics industry carbon emissions and the decoupling between freight volume.

\[ EP_{E-F} = \frac{(C_{t+1} - C_t)}{C_t} \frac{1}{(F_{t+1} - F_t)} / F_t \]  

\((3)\)

\(EP_{E-F}\) is the decoupling index between logistics carbon emission and freight volume; \(C_t\) stands for the logistics carbon at the time of \(t\); \(C_{t+1}\) stands for the carbon emission of logistics industry at the time of \(t+1\); \(F_t\) stands for the logistics freight volume at the time of \(t\); \(F_{t+1}\) refers to the freight volume of logistics at the time of \(t+1\).
For the two decoupling relationships, each index includes six decoupling types: strong decoupling, strong negative decoupling, weak decoupling, expansionary negative decoupling, weak negative decoupling, and recessionary decoupling (as shown in Table 2). Among them, strong decoupling is the most ideal state and strong negative decoupling is the least ideal state.

| Decoupling state       | Characteristics of decoupling between energy consumption and freight volume of logistics industry | Characteristics of decoupling between logistics carbon emission and freight volume |
|------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Strong decoupling      | Freight volume increases, energy consumption drops                                              | Freight traffic is up and carbon emissions are down                              |
| Strong negative        | Freight volume decreases, energy consumption rises                                              | Freight volumes are down and carbon emissions are up                             |
| decoupling             |                                                                                                 |                                                                                  |
| Weak decoupling        | Freight volume increases, energy consumption rises, energy consumption rises rate is lower than freight volume growth rate | The increase of freight volume and carbon emission is lower than that of freight volume |
| Expansionary negative  | Freight volume increases, energy consumption rises, energy consumption rises rate is higher than freight volume growth rate | Freight volume growth, carbon emissions rise, carbon emissions rise faster than freight volume growth |
| decoupling             |                                                                                                 |                                                                                  |
| Weak negative          | The decrease of freight volume and energy consumption is lower than that of freight volume      | The decrease of freight volume and carbon emission is lower than the increase of freight volume |
| decoupling             |                                                                                                 |                                                                                  |
| Recessionary           | The decrease of freight volume and energy consumption is higher than the increase of freight volume | The decrease of freight volume and carbon emission is higher than the increase of freight volume |
| decoupling             |                                                                                                 |                                                                                  |

4. Case Study

4.1. Energy consumption and carbon emissions
As logistics industry is a new industry, there is no clear classified data of logistics industry in China's statistical yearbook data. Considering that 85% of the output value of logistics industry comes from warehousing, postal service and transportation industry, therefore, the energy consumption of warehousing, postal service and transportation industry were selected to estimate the development trend of energy consumption of logistics industry.

![Figure 1. Energy consumption and carbon emission of China's logistics industry](image-url)
It can be seen from figure 1 that: (1) the energy consumption of China's logistics industry is in a sustained and rapid growth stage, rising from 236,918,400 tons of standard coal in 2009 to 396,512,100 tons in 2016. The energy consumption in 2016 is about 1.67 times of that in 2000. (2) During the period from 2009 to 2016, the energy consumption of logistics industry in the national energy consumption is in a steady rising stage, from 7.05% in 2009 to 9.1% in 2016, which is in line with the logistics demand is growing, logistics industry in the national economy is increasingly valued. (3) The carbon dioxide emissions of China's logistics industry have been showing a growing trend from 2009 to 2016, from 123,361,300 tons in 2009 to 188,8384 tons in 2016.

Based on the analysis of the relationship between energy consumption and carbon emission of the logistics industry, the slope of the energy consumption curve is decreasing year by year, which indicates that the growth trend of carbon emission of the logistics industry in China is slowing down, that the reduction of energy consumption plays a certain role in carbon emission, and that the energy consumption structure of the logistics industry in China is gradually becoming reasonable. In 2009-2016 China's logistics industry, according to data from the energy consumption of coal, crude oil, diesel oil, fuel oil consumption accounts for the proportion of overall energy consumption by 1.93%, 0.925%, 48.54% and 7.54% down to 0.73%, 0.08%, 40.67% and 5.45%, and gasoline, kerosene, natural gas and electricity consumption proportion by increased 17.9%, 8.16%, 0.51%, and 3.46% to 20.45%, 10.45%, 0.85% and 4.2%. It indicates that the reduction of gasoline, kerosene, natural gas and electricity consumption and the increase of coal, crude oil, diesel oil and fuel oil consumption will promote the carbon emission of the logistics industry.

4.2. Decoupling relationship between energy consumption, carbon emission and logistics demand in logistics industry

According to formula (2) and (3) and table 2, decoupling status of energy consumption and logistics freight volume of warehousing and transportation industry and decoupling status of carbon emission and logistics freight volume of warehousing and transportation industry are calculated. Decoupling analysis results are shown in table 3.

| Year | Growth rate of freight volume (%) | Growth rate of energy consumption (%) | Growth rate of carbon emissions (%) | Decoupling of energy consumption from freight volume | Decoupling of carbon emissions from freight volumes |
|------|----------------------------------|--------------------------------------|-----------------------------------|---------------------------------------------------|---------------------------------------------------|
| 2010 | 14.75                            | 10.03                                | 9.50                              | Weak decoupling                                   | Weak decoupling                                   |
| 2011 | 14.04                            | 9.46                                 | 7.80                              | Weak decoupling                                   | Weak decoupling                                   |
| 2012 | 10.91                            | 10.48                                | 11.05                             | Weak decoupling                                   | Expansionary negative decoupling                  |
| 2013 | -0.04                            | 10.45                                | 6.07                              | Strong negative decoupling                         | Strong negative decoupling                         |
| 2014 | 1.67                             | 4.36                                 | 2.94                              | Expansionary negative decoupling                   | Expansionary negative decoupling                   |
| 2015 | 0.21                             | 5.45                                 | 4.82                              | Expansionary negative decoupling                   | Expansionary negative decoupling                   |
| 2016 | 5.05                             | 3.48                                 | 2.03                              | Weak decoupling                                   | Weak decoupling                                   |

According to table 3, it can be seen that: (1) Between 2010 and 2013, the logistics industry energy consumption and logistics freight volume are in a weak decoupling state, which indicates that China attaches importance to the logistics industry industrial structure upgrade, optimizing its energy structure, implementing energy-saving efficiency development strategy. In 2013, due to the economic transition period, there was a strong negative decoupling state. From 2014 to 2015, there was an expansionary negative decoupling state. In 2016, there was a weak decoupling state again. (2) In 2010 and 2011, the
carbon emission of logistics industry and logistics freight volume were in a weak decoupling state, it was in expansionary negative decoupling state in 2012, it was in a strong negative decoupling state in 2013, it was in expansionary negative decoupling state in 2014 and 2015, and it was in weak decoupling state in 2016. This shows that environmental issues are increasingly valued by people, carbon emission has been introduced as a constraint factor of logistics planning, the concept of low-carbon logistics development is getting more and more attention from the government, industry and organizations, and the low-carbon sustainable development model is being promoted in the critical period. At present, the development of logistics industry has entered a transitional period, and the growth of freight volume has slowed down. (3) The decoupling of energy consumption, carbon emission and freight volume in the logistics industry shows that China's logistics industry is trying to deal with the energy and climate crisis, energy saving and emission reduction has certain effect, but with the deepening of economic development mode reform, the implementation of energy saving and emission reduction measures also need to be accelerated.

5. Suggestion
According to the 2009-2016 China's logistics industry energy consumption and carbon emissions calculation data, quantitative analysis and dynamic decoupling analysis, conclusion is as follows: (1) The demand of China's logistics industry and energy consumption is dynamic decoupling, it can be roughly divided into three stages: weak decoupling of 2010-2012, negative decoupling of 2013-2015, and weak decoupling of 2016. (2) Improve energy efficiency supplemented by energy structure adjustment is to achieve the logistics industry demand and energy consumption and carbon emissions decoupling key.

With the logistics industry from extensive growth mode to intensive growth mode, we can consider the following suggestions for energy saving and emission reduction: (1) In order to reduce energy consumption and carbon emission, integrating logistics resources, improving the service level and operation efficiency of the industry. (2) Strengthening the research and development and promotion of energy saving and emission reduction technology. (3) Developing multi-modal transport and choosing the low-carbon transport mode at the first priority. (4) Based on supply chain collaborative management, reducing the carbon footprint of the whole supply chain of the logistics industry. (5) Formulating appropriate carbon emission policies to guide the logistics industry to save energy and reduce emissions.

References
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