Multiple regression analysis based on carbon emissions from aviation logistics in Henan Province

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Abstract. In this paper, we analyze the relationship of carbon emission from aviation logistics with the added value of Henan Province's transportation, warehousing, post, and telecommunications industry and the total population of Henan Province from 1997 to 2015. First, we calculate the energy consumption of four types of energy (fuel, gasoline, kerosene and fuel oil) to obtain the carbon emissions of four types of energy. Second, we obtain the estimated energy consumption of aviation logistics in Henan Province through the analysis of the proportion of air cargo. Through analysis, we find that the added value of the transportation, warehousing, post, and telecommunications industry in Henan Province and the total population of Henan Province plays a strong role in promoting the carbon emissions of Henan Province's aviation logistics. Among them, the influence of the added value of the transportation, warehousing, and postal and telecommunications industries in Henan Province is relatively strong.

1. Introduction
In recent years, climate change has become an urgent issue of global concern. Building a resource-saving and environment-friendly society is the common responsibility of the international community. As an important economic activity in today's society, logistics is a major energy consumer and a major carbon emitter [1-3]. Among various modes of transportation, air transportation has the highest unit energy consumption. Furthermore, pollutant emissions from air transport have a greater impact on climate change than other modes of transport, and the way of influence is also more direct [4-5]. The development of low carbonization of aviation logistics has become a global focus. Therefore, studying the carbon emissions of aviation logistics has great significance for the improvement of industry competitiveness and the realization of sustainable development.

On March 8, 2013, the State Council of the People's Republic of China approved the “Zhengzhou Airport Economic Comprehensive Experimental Zone Development Plan (2013-2025)”, which marked the official establishment of the country's first state-level airport economic experimental zone. The planned area of Zhengzhou Airport is 415 square kilometers. It is an integrated hub combining aviation, high-speed rail, intercity railway, subway, and expressway. In addition, it is also an aviation
economy and aviation metropolitan area centered on the Xinzheng Comprehensive Bonded Zone near Zhengzhou Xinzheng International Airport.

Zhengzhou Xinzheng International Airport has formed a network of hub routes covering major economies in the world. This directly led to the rapid development of the logistics industry in Henan Province. In 2016, the total social logistics in Henan Province reached 10.1 trillion yuan, with an increase of 8.8%. The added value of the logistics industry reached 213 billion yuan, increased by 9.1%, accounting for 5.3% of the total production value. Key areas such as cold-chain transportation, express delivery, e-commerce, and aviation logistics have developed rapidly. The consumption of fresh products reached 7.1 million tons; the volume of express delivery business reached 840 million pieces, which witnessed an increase of 63%; Zhengzhou Xinzheng International Airport has a cargo throughput of 457,000 tons, ranking 7th in the country; the volume of e-commerce transactions exceeded one trillion yuan, with an increase of 30%, and the scale of cross-border e-commerce retail import and export business ranked first in the country.

Against the background of the continuous development of the logistics industry in Henan Province, the development of green logistics is also an important topic. The Henan Government mentioned in the Overall Work-plan for Green Transportation Promotion Actions that it is necessary to continue promoting the adjustment of transportation structure and coordinating the development of various modes of transportation such as railways, highways, waterways and civil aviation. Meanwhile, The Government must vigorously promote the development of efficient transportation organization modes such as multimodal transport, semitrailer swap transport, and joint distribution, and accelerate the construction of a modern integrated transportation system.

The paper proceeds as follows. Section 1 provides an introduction. Section 2 discusses the emission intensity of different modes of transportation. Sections 3 summarizes the data. Section 4 presents the empirical model and findings. Section 5 concludes.

2. The emission intensity of different modes of transportation

Civil aviation is the focus of China's energy conservation and emission reduction [6]. The energy conservation and emission reduction targets of the 13th Five-Year Plan have placed high demands on the civil aviation industry. According to the 13th Five-Year Plan, the level of green transportation and low carbonization of civil aviation transportation will be significantly improved, and a green civil aviation standard system will be established by 2020. The new airport waste-free and sewage treatment rate shall exceed 90%. And compared with the 12th Five-Year Plan, the average energy consumption and carbon dioxide emissions of industrial units' transportation turnover shall decrease by more than 4%, and passenger throughput energy consumption of the industry transport airport unit by more than 15%.

| Transportation | Running speed(km/h) | Passenger capacity (person) | Main energy Source | Unit | Per capita carbon emissions(kg) |
|----------------|---------------------|-----------------------------|-------------------|------|-------------------------------|
| Highway        |                     |                             |                   |      |                               |
| Small car      | 100                 | 4                           | Gasoline          | Kg   | 5.85                          |
| Bus            | 90                  | 19                          | Diesel            | Kg   | 3.26                          |
| Aviation       |                     |                             |                   |      |                               |
| Large aircraft | 800                 | 300                         | Aviation kerosene | Kg   | 8.05                          |
| Medium aircraft| 800                 | 150                         | Aviation kerosene | Kg   | 9.05                          |
| Small air plane| 800                 | 50                          | Aviation kerosene | Kg   | 12.07                         |
| Ordinary railway| Speed train         | 1 200                       | Diesel            | Kg   | 1.09                          |
| High-speed railway| D-driver EMU       | 200                         | Electric power    | Kwh  | 1.56                          |
|                | G-driver EMU        | 300                         | Electric power    | Kwh  | 1.91                          |
It can be seen from Table 1 that air transport has the highest intensity of carbon emissions in various modes of transport, which greatly outclasses the emissions of road and railways. Additionally, small aircraft have a higher carbon emission intensity than large and medium-sized aircraft. Therefore, our analysis of the factors affecting the greening of aviation logistics plays a vital role in the overall development of green logistics.

3. Data
Through the analysis of the literature [7-10], we find that the intensity of carbon emissions is directly related to the increase in the total value of transportation, warehousing, post and telecommunications, and the population in Henan Province. Therefore, we choose these two factors for our analysis.

The population is publicly available in this study. Therefore, in the data section, we mainly calculate the carbon emissions of Henan Province.

3.1. Estimation of carbon emissions from the aviation logistics industry at the national level
We use the guidelines for the preparation of provincial greenhouse gas inventories in the China Energy Statistics Yearbook to get a relationship between carbon emissions and energy consumption. The relevant formulas for carbon emissions and energy consumption are as follows:

\[ CE = EC \times ELCV \times UCVC \]  

Where \( CE \) is the carbon emission, \( EC \) is the energy consumption, \( ELCV \) is the low energy calorific value, \( UCVC \) is the unit calorific value carbon content;

Through the analysis of China's energy statistics yearbook (Table 2), we can see the energy consumption of energy in industries such as transportation, warehousing, and postal and telecommunications. Compared with transportation, warehousing, and postal and telecommunications, the characteristics of aviation logistics are very prominent. Four types of energy can typically represent the energy consumption of aviation logistics, which are namely gasoline, kerosene, fuel oil and crude oil. We will not consider the carbon emissions of electricity consumption, since it can be relatively low if the carbon emissions in the energy production process are not considered. Since aviation mainly uses gasoline, kerosene, fuel oil, crude oil, and electricity, we mainly use these indicators to make predictions.

Table 2. Common energy carbon emission coefficient

| Energy type                  | Unit calorific value carbon content (Tons of carbon / trillion joules) | Low energy calorific value (Billion joules / ton) |
|------------------------------|-------------------------------------------------------------------------|-----------------------------------------------|
| Raw coal                     | 26.8                                                                    | 209.08                                        |
| Washed coal                  | 25.8                                                                    | 263.44                                        |
| Coke                         | 29.2                                                                    | 284.35                                        |
| Gasoline                     | 18.9                                                                    | 430.70                                        |
| Kerosene                     | 19.5                                                                    | 430.70                                        |
| Diesel                       | 20.2                                                                    | 426.52                                        |
| Natural gas                  | 15.3                                                                    | 389.31                                        |
| Liquefied petroleum gas      | 17.2                                                                    | 501.78                                        |
| Crude                        | 20.0                                                                    | 418.16                                        |
| Fuel oil                     | 21.1                                                                    | 418.16                                        |
| Coke oven gas                | 12.1                                                                    | 173.53                                        |
| Refinery dry gas             | 18.2                                                                    | 460.55                                        |
| Electric power               | —                                                                       | 35.96 (100 million joules / kwh)               |
| Heat                         | 9.46                                                                    | —                                             |

\(^a\) Source: compiled by the author according to the China Energy Statistical Yearbook and the Provincial Greenhouse Gas Inventory Compilation Guide.
Taking crude oil as an example, the relevant formula is as follows:

\[
\text{ELCV (100 million joules) = crude oil consumption (tons) } \times 501.78
\]

\[
\text{UCVC (tonnes of carbon) = ELCV (trillion joules) } \times 17.2
\]

The carbon dioxide emissions of the logistics industry can be summed up by the total amount of carbon dioxide emissions from various energy consumption. According to the calculation method of IPCC 2007, the carbon oxidation factor is 1, and the carbon dioxide emission of the logistics industry can be calculated by the following formula.

\[
\text{CO}_2 = \sum_{i=1}^{n} w_i \times P_i \times (44/12)
\]

Where \( w_i \) is the unit calorific value carbon content of the i-th energy source, \( P_i \) is the energy low-level calorific value of the i-th type energy source, and \( E_i \) is the consumption amount of the i-th type energy source. 44 and 12 represent the molecular weights of carbon dioxide and elemental carbon, respectively.

After calculation, the total amount of carbon emissions is obtained (table 3).

Table 3. Total CO2 and carbon emissions corresponding to the four types of energy consumption in 1997-2015

| Year | Total carbon dioxide emissions (10,000 tons) | Total carbon emissions (10,000 tons) |
|------|--------------------------------------------|-------------------------------------|
| 1997 | 1945                                       | 7132                                |
| 1998 | 1937                                       | 7102                                |
| 1999 | 2304                                       | 8447                                |
| 2000 | 2442                                       | 8954                                |
| 2001 | 2488                                       | 9122                                |
| 2002 | 2624                                       | 9623                                |
| 2003 | 2952                                       | 10824                               |
| 2004 | 3637                                       | 13334                               |
| 2005 | 3832                                       | 14052                               |
| 2006 | 4269                                       | 15652                               |
| 2007 | 4502                                       | 16507                               |
| 2008 | 4601                                       | 16870                               |
| 2009 | 4628                                       | 16969                               |
| 2010 | 5199                                       | 19065                               |
| 2011 | 5345                                       | 19598                               |
| 2012 | 5820                                       | 21339                               |
| 2013 | 6569                                       | 24085                               |
| 2014 | 6940                                       | 25448                               |
| 2015 | 7658                                       | 28080                               |

3.2. Estimation of carbon emissions from the aviation logistics industry at Henan Province level

In the analysis of aviation logistics, we mainly take the development of the civil aviation industry as an example. The cargo and mail throughput of the airport is an important indicator. Therefore, we use the cargo and mail throughput as a percentage to calculate the proportion of carbon emissions from aviation logistics in Henan Province to the national carbon emissions. Since the energy consumption data of the provinces and sub-sectors are difficult to obtain, we use the airport cargo and mail volume indicators to estimate the percentage of carbon emissions corresponding to the energy consumption of Henan Province. Next, we convert the four types of energy carbon emissions of the country into the carbon emissions of aviation logistics in Henan Province. (Table 4) Since the cargo volume of the Civil Aviation Administration of China can only inquire about the volume of goods in the 2003-2016 year, we have to discard the values of some years.
Table 4. Corresponding Henan Province Aviation Logistics Carbon Emissions Estimate in 2003-2015

| year | Total carbon emissions (10,000 tons) |
|------|-------------------------------------|
| 2003 | 54                                  |
| 2004 | 67                                  |
| 2005 | 99                                  |
| 2006 | 106                                 |
| 2007 | 126                                 |
| 2008 | 123                                 |
| 2009 | 127                                 |
| 2010 | 145                                 |
| 2011 | 174                                 |
| 2012 | 269                                 |
| 2013 | 489                                 |
| 2014 | 695                                 |
| 2015 | 804                                 |

4. Empirical analysis

4.1. model

The basic model is as follows:

\[ D = F \text{ (increased value of GDP in the transportation industry, population)} \]  \hspace{1cm} (5)

\( D \) is the carbon emission value of aviation logistics in Henan Province.

4.2. Results

We used SPSS software to perform multiple linear regression analysis and nonlinear regression analysis on our Henan aviation logistics carbon emission estimates. The explanatory variables we selected are the added value of the transportation, warehousing, post and telecommunications industry in Henan Province, and the population and year of Henan Province.

The model formula we obtained through multiple linear regression analysis is:

\[ D = -23117329.1 + 6329.018 \times \text{TIGDP} + 2035.222 \times \text{POP} \]  \hspace{1cm} (6)

Our goodness of fit is 0.936, and the adjusted goodness of fit is 0.923, which proves that our model fits well. But it may also be because we have a small number of independent variables. The overall significance of the entire equation is taken as an example of F, with an F value of 73.393. It can be seen that the explanatory variables we have chosen have a good interpretation of the variables being interpreted. That is to say, the added value of the transportation, warehousing, post, and telecommunications industry in Henan Province, the population of Henan Province and the year has a greater impact on the carbon emissions of Henan's aviation logistics industry.

For the analysis of the coefficients of the explanatory variables, the slope coefficients of the two explanatory variables are all positive, so there is no problem of pseudo-regression. The t value of the slope coefficient of the added value of the transportation, warehousing, and postal and telecommunications industries in Henan Province is equal to 11.943. This shows that the added value of the transportation, warehousing, and postal and telecommunications industries has a greater impact on the carbon emissions of aviation logistics, and the impact is significant. The t value of the slope coefficient of the population is 1.093, which is not significant. Therefore, we judge that the population has no significant impact on aviation logistics carbon emissions.
5. Conclusion
The result of multivariate regression analysis suggested that the added value of the transportation, warehousing, and postal and telecommunications industries may well explain the carbon emission intensity of aviation logistics. That is to say, the added value of the transportation, warehousing, and postal and telecommunications industries has a strong correlation with the carbon emissions of aviation logistics.

There may be two possible improvement which may require further efforts. First, due to the small number of explanatory variables we have selected and the inaccuracy of the estimated carbon emissions. Multivariate linear regression is only a trend regression analysis of the prediction of aviation logistics carbon emissions. And thus, the added value of transportation, warehousing, and postal and telecommunications industry and the carbon emissions of aviation logistics is only relevant in terms of numerical value or trend. Second, the added value of GDP in transportation industry and population are not the only causes of the increased carbon emissions in aviation logistics. In order to have a better insight of the carbon emission in aviation logistics, more explanatory variables that are as crucial shall be taken into account. By then, the efficacy of the model shall be improved and we can gain a better understanding of the factors that cause carbon emission.

Despite from the trifle imperfection, the conclusion that the added value of the transportation, warehousing, and postal and telecommunications industries has a good explanation for the carbon emission intensity of aviation logistics has been illustrated by the multivariate regression analysis. We can use the credible conclusion to predict the trends in carbon emissions from aviation logistics in Henan Province in the next few years.

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