Research on energy consumption of Beijing transportation industry based on LMDI method

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Abstract. Beijing, as the capital of China, has a rapid economic development and developed transportation industry. In recent years, the output value of transportation industry of Beijing has been growing rapidly. At the same time, it also accompanied by a large amount of energy consumption. With the energy and environmental problems increasingly prominent, it is particularly important to build a resource-saving and environment-friendly transportation industry. Based on this, the paper used LMDI method to analyse the factors affecting the energy consumption of Beijing transportation industry for the year 2005-2016. The results show that the energy structure, energy intensity and freight turnover of per GDP inhibit the energy consumption, and the freight turnover promote the energy consumption, in which, the freight turnover is the key factor to restrain energy consumption. Therefore, certain technical means should be taken out to reduce energy consumption and the pollution on environment, which has a certain practical significance in improving the environment of Beijing.

1. Introduction

1.1. Background and Significance
Transportation industry is one of the basic industrial sectors of the national economy, it is the link between logistics and people in social activities. The development of transportation industry is rapid, but, there is also accompanied by a large amount of energy consumption in transport process. Beijing as the capital of China is the core of China’s transportation hub. The energy consumption of Beijing's transportation industry is huge, which is one of the main energy industries in Beijing. In recent years, Beijing's economy has developed rapidly, from 2005 to 2016, the GDP of Beijing increased from 688.631 billion yuan to 2489.926 billion yuan, with an annual growth rate of 6.47%. Beijing's economic development led to the development of Beijing's transportation industry at the same time. In 2016, the output value of Beijing's transportation industry reached 106.1 billion yuan, with the average annual growth rate of 4.04% compared to 2005. In 2005, Beijing's energy consumption was 55.219 million tons of standard coal, and 2016 it increased to 69.617 million tons of standard coal, with an annual growth rate of 2.13%. From 2005 to 2016, the energy consumption of Beijing transportation industry rose from 5.634 million tons of standard coal to 13.127 million tons of standard coal. In 2016, the energy consumption was 2 times than that of 2005, with an average annual growth rate of 7.99%. It can be seen that the annual average growth rate of the output value of Beijing's transportation industry is lower than the whole city, but the energy consumption is much higher than the average speed of the whole social
energy consumption. In order to construct a resource saving, environment friendly and harmonious transportation, it is necessary to research the factors that influence energy consumption.

Therefore, this paper applies the LMDI method to study the influence factors of energy consumption of Beijing transportation industry, so as to improve the energy utilization rate and the air quality, which has a certain practical significance on the formulation of energy policy and the development of transportation industry.

1.2. Literature Review
In the past few decades, there are two kinds of decomposition methods which are commonly used, namely, Structural Decomposition Analysis SDA and Index Decomposition Analysis IDA. Hoekstra and van den Bergh (2003) made a detailed comparison between the two methods and showed the SDA method is based on the input-output table, which updated almost every five years in China, but, IDA only needs to use the Department's total data, and is applicable to the decomposition model based on time series with less data, thus, IDA is widely used in the study of energy consumption problems [1]. Ang and Zhang (2000) and Sun J W (1998) studied the IDA method and divided it into two methods: Laspeyres Index Decomposition and Divisia Index Decomposition [2, 3]. Ang (2004) found Logarithmic Mean Divisia Index (LMDI) is the best and most effective method in all index models, because, it can deal with the zero-value problem in the data, eliminate the incomplete residuals which can’t be explained, and make the process and results more simple and intuitive [4]. Therefore, it is widely used by domestic and foreign scholars in the study of energy consumption and carbon dioxide emission.

P. Fernández González et al (2014) explored the variation in aggregate energy consumption in the EU-27-member states for the 2001–2008 period with LMDI method [5]. José M. Cansino et al (2015) applied LMDI method to assess the contribution of drivers of CO2 emissions for the 1995-2009 period [6]. Houda Achour and Mounir Belloumi (2016) identified the driving factors in transportation energy consumption for the case of Tunisia by using the LMDI over the period 1985-2014 [7]. In domestic researches, Wang et al (2014) analyzed the driving factors dominating China’s energy consumption over the period 1991-2011 with the LMDI [8]. Zhang et al (2016) used the method to explore the driving factors of carbon emission intensity (CI) in 29 Chinese provinces [9].

1.3. Structure of article
The remainder of this paper is structured as follows. Section 2 discusses the data sources and introduce the LMDI decomposition model. Section 3 analyzes the energy consumption of Beijing transportation industry based on LMDI results. Section 4 presents the conclusions and policy implications.

2. Data sources and LMDI decomposition model

2.1. Data Sources
The data used in paper include economic value, freight turnover and 8 terminal energy sources like coal, gasoline, kerosene, diesel, natural gas, liquefied petroleum gas, thermal and electric power of Beijing transportation industry, which are derived from the Beijing statistical yearbook. Due to the energy consumption data of transportation, warehousing and postal are mostly generated by transportation, so, it is used as the data of Beijing transportation industry. Different from other literatures, the paper studies the energy consumption from the perspective of the whole transportation industry in Beijing, so, it does not distinguish the mode of transportation. Compared with freight volume, freight turnover volume can better indicate the development status of transportation industry. Therefore, freight turnover volume is taken as the research index.

2.2. LMDI decomposition model
Quantitative study of influencing factors will help to further study the energy consumption problem of Beijing transportation industry. The LMDI model can be constructed as follows:
\[ E^t = \sum E_i^t = \sum \frac{E_i^t}{G^t} \times \frac{G^t}{F^t} \times F^t \] (1)

\[ E^t: \text{The total energy consumption of transportation industry of } t \text{ year;} \]
\[ E_i^t: \text{The final energy type } i \text{ of } t \text{ year; } \]
\[ G^t: \text{The GDP of transportation industry in } t \text{ year; } \]
\[ F^t: \text{The turnover of goods in } t \text{ year.}\]
From the base year to the target year \( t \), (1) can also be expressed as follows:

\[ E^t = \sum S_i^t \times I^t \times H^t \times F^t \] (2)

\[ S_i^t: \text{Energy Structure; } I^t: \text{Energy intensity; } \]
\[ H^t: \text{The impact of transportation industry on the turnover of goods} \]

According to (2), the energy change volume of Beijing transportation industry can be divided into 4 influencing factors.

\[ E^t - E^0 = E_{\text{tot}} = \Delta E_S + \Delta E_I + \Delta E_H + \Delta E_F \] (3)

\[ \Delta E_S = \sum w_i \ln \left( \frac{S_i^t}{S_i^0} \right) \quad \Delta E_I = \sum w_i \ln \left( \frac{I_i^t}{I_i^0} \right) \]
\[ \Delta E_H = \sum w_i \ln \left( \frac{H_i^t}{H_i^0} \right) \quad \Delta E_F = \sum w_i \ln \left( \frac{F_i^t}{F_i^0} \right) \]

\[ w_i = \frac{E_i^t - E_i^0}{\ln E_i^t - \ln E_i^0} \]
Assuming that, \( \beta = H^{-1} \),

\[ \Delta E_F = \sum w_i \ln \left( \frac{\beta_i^t}{\beta_i^0} \right) = \sum w_i \ln \left( \frac{(H^{-1})_i^t}{(H^{-1})_i^0} \right) = \sum w_i \ln \frac{H_i^0}{H_i^t} \]
\[ = \sum w_i \ln \left( \frac{H_i^t}{H_i^0} \right)^{-1} = - \sum w_i \ln \left( \frac{H_i^t}{H_i^0} \right) \] (4)

According to (3) and (4), we can see that the inverse number of \( H \) represents the freight turnover volume of per unit GDP. If the calculated result is positive, it means that the freight turnover of unit GDP restrains the energy consumption of transportation industry, otherwise, it promotes the energy consumption of transportation industry.

3. Decomposition results of LMDI

In this paper, the time series decomposition method is used to decompose the energy consumption and influence factors of Beijing transportation industry, the decomposition results are shown in Table 1 and Table 2.
Table 1. Decomposition results of energy consumption in Beijing transportation industry (Ten-thousand-ton standard coal).

| Year       | $\Delta ES$ | $\Delta EI$ | $\Delta EH$ | $\Delta EF$ | $\Delta E_{tot}$ |
|------------|-------------|-------------|-------------|-------------|------------------|
| 2005-2006  | 0.103       | 57.845      | 104.744     | -40.554     | 122.138          |
| 2006-2007  | 0.121       | 41.120      | 20.614      | 37.282      | 99.137           |
| 2007-2008  | 0.157       | 102.050     | -3.836      | 8.367       | 106.737          |
| 2008-2009  | 0.016       | -58.824     | 99.036      | -23.011     | 17.217           |
| 2009-2010  | 0.043       | -138.244    | 78.745      | 126.993     | 67.537           |
| 2010-2011  | 0.004       | -58.932     | -49.804     | 164.475     | 55.743           |
| 2011-2012  | 0.005       | 0.619       | -23.328     | 31.682      | 8.978            |
| 2012-2013  | 0.016       | -8.094      | 1.126       | 62.159      | 55.206           |
| 2013-2014  | 0.003       | -33.812     | 97.343      | -12.128     | 51.404           |
| 2014-2015  | 0.014       | -6.213      | 119.389     | -80.190     | 33.000           |
| 2015-2016  | 0.027       | -27.924     | 2.032       | 81.066      | 55.201           |
| Total      | 0.589       | -186.645    | 448.963     | 354.191     | 617.098          |

Table 2. Decomposition results of energy consumption in Beijing transportation industry (%).

| Year       | $\Delta ES$ | $\Delta EI$ | $\Delta EH$ | $\Delta EF$ | $\Delta E_{tot}$ |
|------------|-------------|-------------|-------------|-------------|------------------|
| 2005-2006  | 0.085       | 47.360      | 85.758      | -33.203     | 100              |
| 2006-2007  | 0.122       | 41.478      | 20.794      | 37.606      | 100              |
| 2007-2008  | 0.147       | 95.608      | -3.594      | 7.839       | 1007             |
| 2008-2009  | 0.095       | -341.669    | 575.232     | -133.658    | 100              |
| 2009-2010  | 0.064       | -204.693    | 116.595     | 188.034     | 100              |
| 2010-2011  | 0.007       | -105.722    | -89.347     | 295.061     | 100              |
| 2011-2012  | 0.053       | 6.893       | -259.826    | 352.880     | 100              |
| 2012-2013  | 0.028       | -14.662     | 2.039       | 112.595     | 100              |
| 2013-2014  | 0.005       | -65.777     | 189.366     | -23.594     | 100              |
| 2014-2015  | 0.043       | -18.827     | 361.782     | -242.998    | 100              |
| 2015-2016  | 0.049       | -50.587     | 3.681       | 146.857     | 100              |
| Total      | 0.076       | -19.398     | 66.349      | 52.974      | 100              |

In order to facilitate analysis, Table 1 can be represented in the histogram as shown in Figure 1 below.

Figure 1. Contribution Degree of Each Influence Factor of Energy Consumption.

From Table 1, Table 2 and Figure 1, we can draw the following results:
3.1. **Energy Structure**  
The Table 1 and Figure 1 shows that the contribution of the contribution of energy structure to the energy consumption of Beijing transportation industry was positive, but the impact is not obvious. The total impact of energy structure on energy consumption in 2005-2016 was only 0.589. This effect almost impossible can be shown in Figure 1.

3.2. **Energy Intensity**  
During the period of 2005-2008, energy intensity played a role in promoting energy consumption in traffic and transportation, and its role was more obvious. But after 2008, the contribution of energy intensity became negative, and the effect of energy consumption was transformed from promotion to inhibition, the impact of energy intensity reduced energy consumption by 1.30411 million tons of standard coal.

3.3. **Freight turnover of per unit GDP**  
Except for the year 2008, 2011 and 2012, $\triangle E_{int}$ showed positive values in the rest years, it can be known that the effect of freight turnover of per unit GDP on energy consumption was promoted in 2008, 2011 and 2012, while the other years were inhibited. According to Table 1, the influence of freight turnover of per unit GDP reduced the energy consumption by 4.4606 million tons of standard coal, Table 2 shows that from 2005 to 2016, the influence of energy intensity made a 19.40% reduction in energy consumption, while, the freight turnover of per unit of GDP make a decreased by 66.35%, which shows the freight turnover of per unit GDP was the main factor inhibiting the energy consumption in Beijing transportation industry.

3.4. **Freight Turnover**  
During the period of 2005 to 2016, the turnover of goods mostly showed the promotion effect, only a few years realized as the inhibitory effect. From Table 1, it is known that the turnover of goods increases energy consumption by 3.56141 million tons of standard coal, at the same time, it can be seen from Table 2 that the rate of growth is up to 52.97%. It shows that there is still a big energy consumption problem in the turnover of goods by the way of transportation.

4. **Conclusion**  
In this paper, the LMDI method is used to analyze the factors affecting the energy consumption of Beijing transportation industry for the year 2005-2016. The results show that energy structure, energy intensity and freight turnover of per GDP inhibit the energy consumption, and freight turnover promote the energy consumption, in which, the freight turnover becomes the key factor to restrain energy consumption. The recommendations can be drawn from LMDI analysis results as follows:

In pursuit of the economic development of the Beijing transportation industry, it is needed to adjust and optimize the transportation mode and the development structure, plan the low carbon traffic infrastructure, accelerate the construction of the Beijing transportation system and improve the level of urban traffic intelligent. Besides, it also needs to increase the research of energy-saving technology, adopt strict technical standards to promote energy conservation in transportation industry, develop and utilize low-carbon, environmentally friendly transport vehicles which uses renewable energy like solar energy and biomass. Efforts should be made to achieve high output value, low energy consumption and low pollution of Beijing transportation industry, so as to further promote the development of Beijing economy.

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