Cargo Transport Energy Consumption Factors Analysis: Based on LMDI Decomposition Technique

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Abstract

The energy constraint is the hot topic in the current global and transportation industry energy consumption keeps increasing. How to evaluate various factors in the carriage of goods by the contribution degree of energy consumption has important significance to reduce the energy consumption of carriage of goods. This paper builds a model of cargo transport energy consumption, using the LMDI decomposition technique to analyze the influence factors of cargo transport consumption of China in 2000-2012. Results show that GDP growth is China the leading factor in the continued growth in energy consumption, degradation of transportation structure cause the growth of energy consumption, the decrease of transport of goods intensity and cargo transportation energy consumption intensity can reduce energy consumption. In this paper, here are the conclusions: the optimization of transport structure and industrial layout and promote technological progress, which is helpful for the decrease of energy consumption of goods.

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consumption growth is at an average annual rate of 15.9%. From the point of view of energy structure, the transportation is given priority to with oil consumption, which aggravated the tension in the China's oil supply. From the point of environmental protection, a lot of energy consumption means that will produce large amounts of pollutant. As the fog haze rising in recent years, the transportation emissions pollution gases have a great relationship with it. Transportation energy consumption growth and the significantly increasing proportion has become the key areas of energy saving and emission reduction in China. Analyzing the main factors influencing the transport of goods industry energy consumption can be of great significance to promote energy efficiency and saving energy, reducing consumption of transportation. The LMDI decomposition of energy consumption is an effective technology to the research of this kind of problem to change the goods into the effect of various factors, quantitatively analysis of the change of factors on the impact of energy consumption.

2. The building of cargo transportation energy consumption model

Decomposition analysis is a kind of quantitatively determining the size of each factor's influence on the research object analysis method that decompose a complex thing into a number of relatively simple things as well as decompose the large system into specific elements [1]. As the research of characteristics in the changes of things and mechanism of a framework for analysis, decomposition analysis has more and more application in energy economy and other research areas [2]. Decomposing goods transportation energy consumption into a combination of various factors and quantitatively analyzing of various factors change on carriage of goods by the influence of changes in energy consumption, become the technology of this kind of problem of research works [3]. Carriage of goods by decomposition analysis first need to build the energy factor decomposition model, which is to decompose the carriage of goods by the affecting factor on the changes of energy consumption, and through the contribution value and contribution of these factors to measure the influence degree.

Railways, highways, waterways, air and pipeline make up transportation system. Kaya identities [4, 5], the analysis method of influence factors such as carbon dioxide emissions, economy, policy and population, can decompose a time of cargo transportation energy consumption into:

$$N_i' = \sum_{i=1}^{5} \frac{N_i'}{p_i'} \times \frac{\sum P_i'}{\sum P'} \times \frac{\sum P'}{GDP'} \times GDP'$$

$$= \sum_{i=1}^{5} S_i' \times \alpha_i' \times l_i' \times k_i' \times GDP'$$

$N_i'$:t period goods transport energy consumption; $N_i'$: i type of cargo during t period goods transport energy consumption; $\sum P_i'$: the whole society revolving quantity of the goods during t period; $p_i'$: i type of the whole society revolving quantity of the goods during t period; $\sum P'$: the freight volume of the whole society during t period; $GDP'$: Gross domestic product during t period; $S_i' = \frac{N_i'}{\sum P_i'}$: General cargo transport energy intensity during t period; $S_i' = \frac{N_i'}{p_i'}$: i type of general cargo transport energy intensity during t period; $\alpha_i' = \frac{p_i'}{\sum P_i'}$ : the proportion of the revolving quantity of the goods in five types(cargo transport
structure); $t' = \frac{\sum P' f_t}{\sum P'}$: The average cargo shipping distance during $t$ period; $k' = \frac{\sum P' g_t}{GDP'}$: The intensity of cargo transportation during $t$ period.

Formula 1 means that a certain time of the change of energy consumption goods comes from cargo transportation energy consumption intensity, the transport of goods structure, cargo transport intensity and the change of GDP.

3. The LMDI decomposition model of cargo transportation energy consumption

Cargo transport energy consumption grows fast and LMDI technology may be used for quantitative analysis of the influence factors. LMDI, namely logarithmic index decomposition method, because of the decomposition, no residual, easy to use, and the consistency of multiplication decomposition and addition decomposition, the uniqueness of the result and the advantages of easy to understand, it gets attention in many decomposition technique, which is widely used in many fields [6].

Cargo transportation energy consumption at 0 and $t$ period is decomposed into available by LMDI addition model:

$$\Delta N = N' - N^0 = \Delta N_S + \Delta N_a + \Delta N_i + \Delta N_k + \Delta N_{GDP} + \Delta N_{res}$$ (2)

$\Delta N_S$, $\Delta N_a$, $\Delta N_i$, $\Delta N_k$, $\Delta N_{GDP}$ respectively mean the change value of cargo transportation energy consumption caused by cargo transport energy consumption intensity change, cargo transport structure, average cargo shipping distance change, cargo transport intensity change and gross domestic product (GDP) change. $\Delta N_{res}$ for the decomposition of residual items.

Specific results of LMDI additive decomposition are shown below:

$$w_i = \frac{N'_i - N^0_i}{\ln(N'_i / N^0_i)}$$

$$\Delta N_S = \sum w_i \ln \frac{S'_i}{S^0_i}$$

$$\Delta N_a = \sum w_i \ln \frac{\alpha'_i}{\alpha^0_i}$$

$$\Delta N_i = \sum w_i \ln \frac{l'_i}{l^0_i}$$

$$\Delta N_k = \sum w_i \ln \frac{k'_i}{k^0_i}$$

$$\Delta N_{GDP} = \sum w_i \ln \frac{GDP'_i}{GDP^0_i}$$

$$\Delta N_{res} = \Delta N - (\Delta N_a + \Delta N_S + \Delta N_i + \Delta N_k + \Delta N_{GDP})$$

$$= N' - N^0 - \sum_{i=1}^{s} w_i \left( \ln \frac{\alpha'_i}{\alpha^0_i} + \ln \frac{S'_i}{S^0_i} + \ln \frac{l'_i}{l^0_i} + \ln \frac{k'_i}{k^0_i} + \ln \frac{GDP'_i}{GDP^0_i} \right)$$

$$= N' - N^0 - \sum_{i=1}^{s} \frac{N'_i - N^0_i}{\ln(N'_i / N^0_i)} \left( \ln \frac{\alpha'_i S'_i l'_i k'_i GDP'_i}{\alpha^0_i S^0_i l^0_i k^0_i GDP^0_i} \right)$$

$$= 0$$
4. The empirical analysis of Chinese cargo transport energy consumption influence factors

4.1. Sample selection and data processing

Railways, highways, waterways, air and pipeline make up transportation system. Highway transportation, according to the transportation system, can be divided into inter-city highway transport and road transport in the city; according to the transportation task properties, can be divided into commercial and non-commercial transport. Waterway transportation including ocean transportation, coastal and inland waterway transport. Based on the 2000-2012 data as sample (except 2007), using annual statistical data of national bureau of statistics, the study of the cargo transport system is limited to domestic inter-city commercial transportation, including railways, highways, waterways (not including ocean transportation), air and pipeline transport. The revolving quantity of the goods in the whole society, transportation structure and the whole society freight are from China's Transportation Yearbook [8]. The average cargo shipping distance is calculated by the revolving quantity of the goods and freight, cargo energy intensity is calculated by literature [4], and the intensity of the carriage of goods by freight is calculated by freight and GDP (GDP is from China Statistical Yearbook [9]). Since the goods energy intensity in 2012 have no related data calculated, use the curve fitting and time series method to get.

4.2 The analysis of influencing factors

Based on the above theoretical analysis of transport ation energy consumption influence factors and index data processing, using the LMDI decomposition addition technique, get the goods transportation energy consumption influence factors as shown in table 1.

Table 1, Calculation results of cargo transport energy consumption influencing factors (tons of standard coal)

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<tr>
<td>Energy consumption intensity</td>
<td>-9077.04</td>
<td>-9420.98</td>
<td>-10111.24</td>
<td>-11208.4</td>
<td>-12722.41</td>
</tr>
<tr>
<td>Cargo transport structure</td>
<td>11256.98</td>
<td>-3.07</td>
<td>-12975.17</td>
<td>-21365.3</td>
<td>-5282.14</td>
</tr>
<tr>
<td>Average cargo shipping distance</td>
<td>-24676.39</td>
<td>12630.46</td>
<td>23803.23</td>
<td>57680.16</td>
<td>26703.98</td>
</tr>
<tr>
<td>Cargo transport intensity</td>
<td>-45299.91</td>
<td>-23239.7</td>
<td>-46899.06</td>
<td>-56763.4</td>
<td>-51406.63</td>
</tr>
<tr>
<td>GDP</td>
<td>60763.08</td>
<td>57886.02</td>
<td>79765.07</td>
<td>116935.8</td>
<td>116045.6</td>
</tr>
<tr>
<td>The total value</td>
<td>-7033.27</td>
<td>37852.73</td>
<td>33582.83</td>
<td>85278.88</td>
<td>73338.4</td>
</tr>
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<tr>
<td>Energy consumption intensity</td>
<td>7741.16</td>
<td>70232.97</td>
<td>22218.06</td>
<td>36549.59</td>
<td>95599.77</td>
</tr>
<tr>
<td>Cargo transport structure</td>
<td>-14244.65</td>
<td>-4422.03</td>
<td>-5005.95</td>
<td>-13011.9</td>
<td>-21911.44</td>
</tr>
<tr>
<td>Average cargo shipping distance</td>
<td>13315.48</td>
<td>-39274.79</td>
<td>22670.17</td>
<td>12092.76</td>
<td>-45520.38</td>
</tr>
<tr>
<td>Cargo transport intensity</td>
<td>-59758.27</td>
<td>4778.83</td>
<td>-56362.68</td>
<td>-80988.9</td>
<td>39022.96</td>
</tr>
<tr>
<td>GDP</td>
<td>137229.53</td>
<td>161135.35</td>
<td>365115.91</td>
<td>425870.6</td>
<td>273469.3</td>
</tr>
<tr>
<td>The total value</td>
<td>84283.21</td>
<td>192450.34</td>
<td>348635.51</td>
<td>380512.2</td>
<td>340660.25</td>
</tr>
</tbody>
</table>

Draw the proportion of result in table 1 making up by "five factors"(energy consumption intensity, cargo transport structure, average cargo shipping distance, cargo transport intensity and GDP).
From figure 1, the "five factors" all have impact on transportation energy consumption. Factors influencing the value positive is said to cause the cargo transport energy consumption growth, and negative means to reduce energy consumption. GDP is positive, indicating that its change caused the increase of cargo energy consumption, and GDP is the leading factor that promotes cargo transport energy consumption increase. The influence of cargo energy intensity and the cargo transport intensity change is generally negative value. This suggests that the changes lead to energy consumption reduce, and the cargo transport intensity is dominant factor for energy consumption reduce. The fluctuations of cargo transport structure and average cargo shipping distance make energy consumption fluctuating.

Carry out the five factors respectively to specific analysis on the influence of the cargo energy consumption as following:

(1) The influence of energy consumption intensity on cargo energy consumption
As can be seen from the figure 2, road transportation energy consumption level is higher and it holds dominant market share, which makes a greater influence on the energy consumption reduction. Although the energy intensity of air transportation is far higher than the rest of the four kinds of mode of transportation, but its market share is small, so the energy intensity of carriage of goods by the influence of the energy saving is weak.

The figure 3 shows that during 2000-2012 five kinds of mode of transportation of energy intensity basically decline year by year, but the change is not so big. It can be seen that technology innovation's influence on energy intensity is slow and it needs a long historical process. Technological advances bring energy intensity decreased, but in a variety of internal transportation way, the rapidness and high quality quantitative offset it, so technology energy saving potential is limited. In all kinds of transportation between unit energy consumption has obvious difference, structure and energy saving potential is bigger. As railway transport and water transport unit energy consumption is much lower than the unit energy consumption of highway and air transport, from the point of view of reducing energy consumption, should reduce highway transportation proportion, while improve the railway and water transportation proportion.

(2) The influence of cargo transport structure on cargo energy consumption

According to the collected data, proportion of railway transportation has fallen sharply, and highway transportation proportion increased dramatically after 2008. Such structure change makes the transportation structure on the carriage of goods by the impact of energy consumption also changes accordingly.

Fig. 4 the influencing proportion of transportation structure for cargo transport energy consumption (%)

Through calculation analysis shows that changes a percentage of each structure of railway transportation, 355 101 tons of standard coal transportation energy consumption changes on average; so the figure of the highway is 2 076 523, the waterway is 367 556, the air is 18 841 230 and the pipeline is 296 742.

After 2008, highway transport occupied the main position, and its energy intensity is relatively high, so the change on road transportation market share to the carriage of goods by the impact of higher energy consumption significantly, largely dominated the transportation structure change on the carriage of goods by the impact of higher energy consumption. Air transport has the greatest effect in the energy intensity change, but its market share is small, the influence on transportation energy consumption is weaker. The mode of transportation of air and highway both energy-intensive cut will make transportation and energy saving. The railways, waterways especially pipeline share rise, although can bring traffic energy consumption rising, is far lower than the high energy consumption share, so the overall transportation energy consumption will decline.

(3) The influence of average cargo shipping distance on cargo energy consumption

In 2000-2012 average cargo shipping distance has fluctuation change, and there is a growing trend as a whole. The influence of average cargo shipping distance on cargo energy consumption has the same change
trend with growth rate, if the growth rate is positive, effect on the change of the transport of goods consumption is positive. Average cargo shipping distance increases indicate that China's industrial distribution led to goods transportation distance increased, making the energy consumption increased. So adjust industrial layout is advantageous to the reduction of energy consumption.

(4) The influence of cargo transport intensity on cargo energy consumption

In 2000-2012 cargo transportation intensity is on the decline as a whole. Before 2006 fallen rapidly, after that gently swings, which has to do with China's industrial structure adjustment. Cargo transport intensity of carriage of goods by the impact of energy consumption proportion is 16.7% in average, which is the most important factor for energy consumption reduction of carriage of the goods. Cargo transport intensity reflects the national economic system on traffic situation of demand and supply. Adjust the industrial structure, reduce the first and second industry scale and improve the expansion of the third industry to reduce the supply and demand for transportation in national economy system so that energy consumption will reduce.

(5) The influence of GDP on cargo energy consumption

According to the calculated data, in 2000-2012 China's GDP growth rate is 13.7% on average, showed a trend of rapid growth. GDP growth prompted the revolving quantity of the goods and freight volume growth, thus makes the rapid growth of energy consumption of carriage of goods. GDP growth caused increase accumulated up to 1.7942 million tons of standard coal consumption, accounting for 70.5% of the total change cumulates in 12 years. GDP plays a leading role in the growth of cargo transport consumption. During the “Twelfth five-year” period, China's annual GDP target is 7% to 8%. Sustained growth in GDP will inevitably bring goods transport energy consumption continues to grow. Therefore, considering the energy consumption intensity, transportation structure, average shipping distance and transport of goods of goods strength in terms of reducing energy consumption is particularly important.

5. Conclusions and recommendations

The ways to reduce cargo transport energy consumption are as follows:

(1) Adjusting and optimizing the structure of cargo transportation, build energy-efficient integrated transportation system.

(2) Promote technological progress, and further reduce the energy consumption intensity.

(3) Optimize the industrial layout and build a new pattern of coordinated development of modern industry, thus reducing the average transport distance of goods.

(4) Optimize the industrial structure and reduce freight volume growth. Reduce the first and second industry proportion, while increase the proportion of the third industry.

References