

# Study on influencing factors of carbon emissions for industrial energy consumption in Dalian based on LMDI model

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**Abstract.** After calculating and analysing the carbon emissions for industrial energy consumption in Dalian during 2007 to 2014, the LMDI model is built to decompose the influencing factors on carbon emissions from the perspectives of energy structure, energy intensity, industrial structure and output scale. As many as 17 types of energy are involved in the calculation of emissions, and based on the specific industrial structure of Dalian, the analysis for the influence on carbon emissions from industrial structure is made from the perspective of light and heavy industry. The result shows, output scale effect is a major contributor for the growth of the carbon emissions for industrial energy consumption in Dalian, while energy intensity effect is the principal inhibitor. Energy structure and industrial structure influence relatively weakly on the energy-consumption emissions, which indicates that the emission reduction potentials from these two perspectives are still not achieved.

## 1. Introduction

The global warming caused by carbon emissions is one of the world top ten environmental issues. As the world's fastest growing developing country, China has made rapid development in economy, but its energy consumption becomes high simultaneously. Among all the economic sectors of China, the energy consumption of industrial sector accounts for 75 percent of the total energy consumption, and the carbon emissions caused by industrial production makes up 83% of total emissions. This means that industry should be strongly concerned if China wants to reduce energy consumption and carbon emissions.

Dalian, which is located in northeast old industrial base, is one of the most important industrial cities in Liaoning province. While Dalian's industry is showing strong growth, the concern about the industrial carbon emissions is increasingly raised. Therefore, it is necessary to calculate and analyze the industrial carbon emissions in Dalian, so as to find a way to control and manage the emissions.

Emission factor method, mass balance method and actual measurement method are the most popular methods for estimating carbon emissions. As the first method proposed by IPCC for calculating carbon emissions, emission factor method is the dominating calculation method. In this method, estimation results are obtained by multiplying emission factors by activity data [1]. Seeing that mass balance method takes too many intermediate processes into consideration and actual measurement method is too detailed [2], emission factor method is the most suitable one for calculating industrial carbon emissions in Dalian.



Decomposition analysis methods could be split into two categories, structure decomposition analysis (SDA) and index decomposition analysis (IDA). While the method of SDA is based on input-output table, and its calculating process is complicated, IDA only needs a smaller amount of data to conduct a multi-level analysis. IDA could be divided into Laspeyres index and Divisia index. Since Divisia index is relatively flexible and it could decompose influencing factors more completely, it is widely used by researchers. Logarithmic Mean Divisia Index (LMDI) is one of the Divisia index methods. With a firmer theoretical foundation, stronger computability and more interpretable result [3], LMDI is considered as an effective decomposition method.

LMDI is widely used to study carbon emissions by researchers in China. Guo[4] uses LMDI method to decompose China's carbon emissions in 1995-2007 at industrial and regional levels. The results show that expansion of economic scale is the most important factor for the continuous carbon emissions growth and the improvement of energy efficiency is the most important to inhibit carbon emissions' growth. Liu et al. [5] decompose carbon intensity by LMDI method into ten driving factors, which covering energy and non-energy related emissions from industrial and household sectors. Wu et al. [6] use the LMDI decomposition method to decompose the factors of energy carbon emissions in Beijing from the year 1995 to 2010. There are also some researchers focusing on the industrial carbon emissions. Shi et al.[7] first discuss characteristics of carbon emissions from carbon emissions and intensity and some other indicators of the industrial economy in Nanjing for the period 2000-2009, and then build LMDI model to unravel the carbon emission mechanism of the energy sector in Nanjing from the perspectives of industrial scale, energy intensity, energy structure, and energy emission intensity.

In this paper, emission factor method is adopted to calculate the carbon emissions for industrial energy consumption in Dalian. And seeing that Dalian relies more on heavy industry than light industry, the carbon emissions generated from these two kinds of industry are calculated separately. Then, LMDI model is built to decompose the influencing factors on carbon emissions from the perspectives of energy structure, energy intensity, industrial structure and output scale.

## **2. Carbon emissions for industrial energy consumption in dalian**

### *2.1. Method*

The calculation of carbon emissions for industrial energy consumption in Dalian is based on the calculation methods provided by IPCC.

The formula for calculating carbon emissions is shown as the following:

$$\text{Emissions} = \text{AD} \times \text{EF} \quad (1)$$

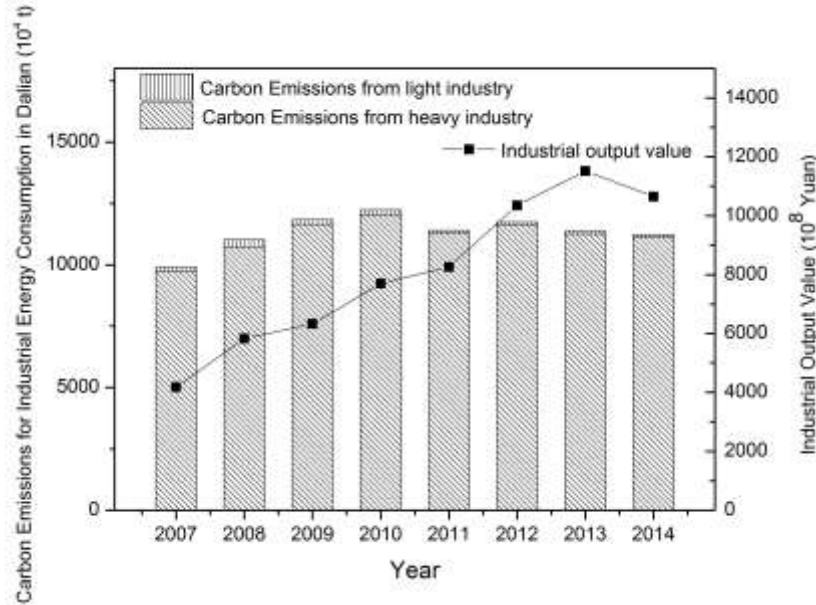
Where Emissions is the total carbon emissions come from burning a certain type of fossil fuels in industrial process, EF is its emission factor, and AD is its activity data.

### *2.2. Result*

During 2007 to 2014, the carbon emissions for industrial energy consumption in Dalian increase steadily in early period, and turn to fluctuate later. From 2007 to 2014, the annual emission is 2701.28, 3006.21, 3228.16, 3271.11, 2990.28, 3065.34, 2930.43,  $2873.86 \times 10^4$  t respectively. Carbon emissions rise an average 1.1% annually during 2007 to 2014, and emissions grow fastest in 2007 by 11.3%. As shown in Figure 1, the industrial carbon emissions show a meagre growth. In 2011, 2013 and 2014, the growth rates are even negative.

During 2007 to 2014, the carbon emissions generated from the energy consumption of light industry averagely make up 1.6% of total emissions. However, the output value made by light industry averagely makes up 23.3% of the gross output. This suggests that, to achieve an equal output, the production heavy industry creates more carbon dioxide than that of light industry. Therefore, adjusting

the proportion of light and heavy industry in Dalian and optimizing the industrial structure are beneficial for reducing the carbon emissions for industrial energy consumption.



**Figure 1.** Carbon Emissions for Industrial Energy Consumption and Gross Industrial Output Value in Dalian

### 3. Decomposition of carbon emissions for industrial energy consumption by LMDI

#### 3.1. Method

Carbon emissions could be influenced by many factors, and each factor has a different influence. In this paper, LMDI model is built to decompose the influencing factors on carbon emissions from the perspectives of energy structure, energy intensity, industrial structure and output scale.

The decomposition formulas are shown as follow:

$$\Delta C_{es} = \sum_i^{17} \sum_j^2 \frac{c_{ij}^t - c_{ij}^0}{\ln c_{ij}^t - \ln c_{ij}^0} \cdot \left[ \ln \left( \frac{E_{ij}}{E_j} \right)^t - \ln \left( \frac{E_{ij}}{E_j} \right)^0 \right] \quad (2)$$

$$\Delta C_{ei} = \sum_i^{17} \sum_j^2 \frac{c_{ij}^t - c_{ij}^0}{\ln c_{ij}^t - \ln c_{ij}^0} \cdot \left[ \ln \left( \frac{E_j}{GVIO_j} \right)^t - \ln \left( \frac{E_j}{GVIO_j} \right)^0 \right] \quad (3)$$

$$\Delta C_{is} = \sum_i^{17} \sum_j^2 \frac{c_{ij}^t - c_{ij}^0}{\ln c_{ij}^t - \ln c_{ij}^0} \cdot \left[ \ln \left( \frac{GVIO_j}{GVIO} \right)^t - \ln \left( \frac{GVIO_j}{GVIO} \right)^0 \right] \quad (4)$$

$$\Delta C_{os} = \sum_i^{17} \sum_j^2 \frac{c_{ij}^t - c_{ij}^0}{\ln c_{ij}^t - \ln c_{ij}^0} \cdot [\ln(GVIO)^t - \ln(GVIO)^0] \quad (5)$$

Where  $\Delta C_{es}$  represents the change of carbon emissions caused by energy structure effect;  $\Delta C_{ei}$  represents the change of carbon emissions caused by energy intensity effect;  $\Delta C_{is}$  represents the change of carbon emissions caused by industrial structure effect;  $\Delta C_{os}$  represents the change of carbon emissions caused by output scale effect.

### 3.2. Result

The result is shown in Table 1.

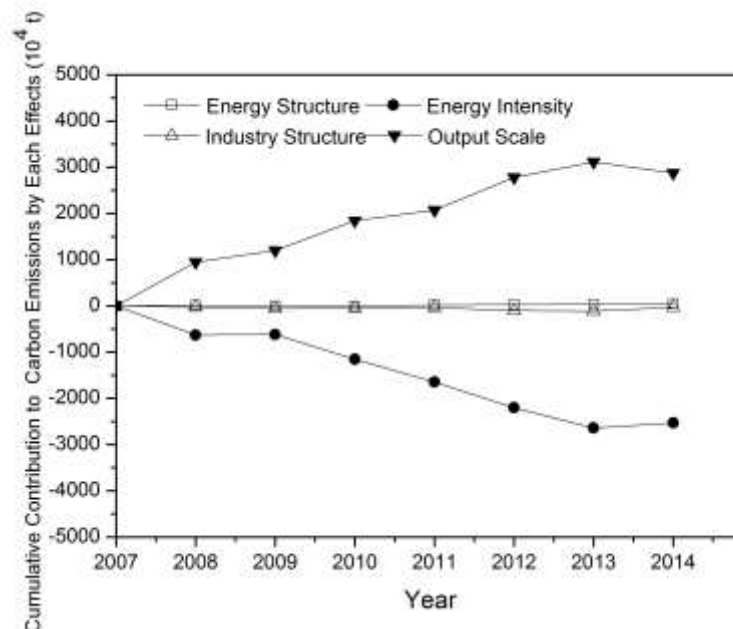
**Table1.** Result of industry energy-related emission decomposition for Dalian, 2007-2014

Unit:  $10^4$  t C

Year	Energy Structure	Energy Intensity	Industrial Structure	Output Scale	Total
2007-2008	11.40	-626.51	-25.56	945.61	304.94
2008-2009	-12.34	10.46	-32.47	256.48	222.13
2009-2010	-5.71	-538.22	12.49	640.52	109.08
2010-2011	30.26	-492.02	7.79	226.88	-227.09
2011-2012	2.95	-555.93	-63.92	708.65	91.77
2012-2013	6.86	-438.23	-7.04	336.50	-101.91
2013-2014	10.80	109.10	81.31	-241.60	-40.40
Total	44.22	-2531.35	-27.40	2873.04	358.51

As shown in Table 1, during 2007 to 2014, carbon emissions for industrial energy consumption in Dalian increase by  $358.51 \times 10^4$  t, to which energy structure effect, energy intensity effect, industrial structure effect and output scale effect contribute 44.22, -2531.35, -27.40,  $2873.04 \times 10^4$  t, respectively. It suggests that energy intensity and output scale are major influencing factors to the carbon emissions for industrial energy consumption in Dalian.

As shown in Figure 2, during 2007 to 2014, output scale effect is a major contributor for the growth of the carbon emissions for industrial energy consumption in Dalian, while energy intensity effect is the principal inhibitor. The decline of carbon emissions caused by energy intensity effect could buffer the increase caused by output scale effect.



**Figure 2.** Decomposition of Cumulative Growth in Carbon Emission for Industrial Energy Consumption

Energy structure and industrial structure influence relatively weakly on the energy-consumption emissions, which indicates that the emission reduction potentials from these two perspectives are still not achieved.

#### 4. Conclusion

In this paper, the carbon emissions for industrial energy consumption in Dalian during 2007 to 2014 is calculated, and the result shows that the industrial carbon emissions do not monotonically increase any more, instead they turn to fluctuate. It suggests the energy conservation policies have achieved an initial success.

The result of LMDI shows that, while output scale effect is a major contributor for the growth of the carbon emissions for industrial energy consumption in Dalian, energy intensity effect could buffer the increase caused by output scale effect. Energy structure and industrial structure show relatively meagre influences on the energy-consumption emissions, which indicates that the emission reduction potentials from these two perspectives are still not achieved.

#### References

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