Using Spatial LMDI to Decompose Electricity Consumption Intensity in Shandong Province from 2015

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Abstract. In this paper, through the construction of spatial LMDI decomposition framework, we decompose the influencing factors of Shandong Province's total electricity consumption intensity from 2015 to 2018 into two parts: city’s economic growth factor and city’s electricity consumption intensity factor. The results show that, in this period, the increase of city’s electricity consumption intensity is the main reason for the increase of total electricity consumption intensity in Shandong Province. However, the city’s economic growth slightly slow down the increase of the total electricity consumption intensity. Compared with other cities, the growth of electricity consumption intensity in Binzhou is the main driving force of total intensity growth, accounting for 69.35%. However, 6 cities (Dezhou, Jining, Jinan, Laiwu, Liaocheng, Zibo) play a negative role in the rise of Shandong's overall electricity consumption intensity.

1. Introduction
The measurement indicators of energy use efficiency, such as the size and change trend of energy intensity, are related to the total energy consumption, carbon emission level and sustainable development capacity (Sun, 1998). Related research topics have been widely concerned by relevant scholars worldwide. Most literatures based on decomposition method measure the contribution of different influencing factors to the change of energy or electricity intensity (Song and Zheng, 2012). Currently, the decomposition model includes structure decomposition analysis (SDA) and index decomposition analysis (IDA) (Wang, et al., 2017). According to Hoekstra et al. (2003), the index decomposition analysis (IDA) is more flexible, only needs the aggregate data. And it can capture the proportion change of different influencing factors from the annual or even monthly time dimension. Furthermore, under certain assumptions, the two kinds of decomposition methods can be derived and transformed from each other (Boer and Paul, 2008).

Of all the IDA methods, LMDI is the most popular one (Sun and Xu, 2011; Fang et al., 2012; Du et al., 2018). Using LMDI, Jimenez and Mercado (2014) pointed out that economic growth is the determinant of energy intensity changes in Latin American countries. Wang et al. (2019) used the LMDI decomposition method to decompose the electricity consumption intensity of China's manufacturing industry from 1990 to 2015. Shi (2008) decomposed the changes of China's industrial energy...
consumption into production effect, structure effect and intensity effect based on LMDI. In order to explore the influencing factors of electricity consumption growth, Li et al. (2016) used LMDI method to decompose the whole industry electricity consumption change in Shandong Province from 2006 to 2012 into activity effect, structure effect and intensity effect.

By reviewing the documents, we find that scholars at home and abroad have more research on the industrial decomposition of energy consumption and energy intensity, but less on the spatial decomposition of energy consumption. In this paper, the spatial LMDI method is used to decompose the change of electricity consumption intensity of each prefecture level city in Shandong Province from 2015, and to explore the impact of each city on the total intensity of Shandong Province.

2. Methodology
As for the traditional Logarithmic Mean Divisia Index (LMDI) method, $V$ is the decomposed variable, $i$ subcategory is marked as $V^1, V^2, V^3, ..., V^i$, $n$ influencing factors were recorded as $x^1, x^2, x^3, ..., x^i$.

$$V = \sum_i V^i = \sum_i x^{1,i} x^{2,i} ... x^{n,i}$$  \hspace{1cm} (1)

$$\Delta V^{tot} = V_{t_1} - V_{t_0} = \Delta V^{x_1} + \Delta V^{x_2} + ... + \Delta V^{x_n}$$  \hspace{1cm} (2)

$\Delta V^{tot}$ is the difference between $V_{t_1}$ and $V_{t_0}$. $V_{t_1}$ and $V_{t_0}$ are the decomposed variable of period $t_0$ and $t_1$. And the contribution level of the $k$th factor in Eq.(2) to $\Delta V^{tot}$ can be calculated by the following formula:

$$L(V^i_{t_1}, V^i_{t_0}) = (V^i_{t_1} - V^i_{t_0})/(\ln V^i_{t_1} - \ln V^i_{t_0})$$  \hspace{1cm} (3)

$$\Delta V^{x_k} = \sum_i L(V^i_{t_1}, V^i_{t_0}) \ln \left( \frac{x^{k,i}_{t_1}}{x^{k,i}_{t_0}} \right) = \sum_i \frac{V^i_{t_1} - V^i_{t_0}}{\ln V^i_{t_1} - \ln V^i_{t_0}} \ln \left( \frac{x^{k,i}_{t_1}}{x^{k,i}_{t_0}} \right)$$  \hspace{1cm} (4)

Based on the idea of traditional LMDI, this paper further constructs the spatial LMDI decomposition method. The overall electricity consumption level of Shandong Province can be expressed as:

$$E = \sum_i E^i = \sum_i \frac{E^i Q^i}{Q} = \sum_i I^i S^i$$  \hspace{1cm} (5)

Where, $E$ is the total electricity consumption level, $E^i$ represents the electricity consumption level of city $i$ in Shandong Province. $Q^i$ represents the economic output of the city $i$, $Q$ represents the total output of Shandong Province. While $I^i$ is the electricity consumption intensity of city $i$, $S^i$ is the proportion of economic output of city $i$ to the total output of Shandong Province.

The electricity consumption intensity of Shandong Province can be further expressed as follow:

$$EI = \frac{E}{Q} = \sum_i \frac{E^i Q^i}{Q} = \sum_i I^i S^i$$  \hspace{1cm} (6)

We record the change of electricity consumption intensity in Shandong Province from $t_0$ to $t_1$ as $\Delta EI$. According to formula (7), $\Delta EI$ is mainly affected by economic growth factor of each city ($\Delta EI^s$) and electricity consumption intensity factor of each city ($\Delta EI^i$).

$$\Delta EI = \frac{\sum_i E^i_{t_1}}{Q_{t_1}} - \frac{\sum_i E^i_{t_0}}{Q_{t_0}} = \Delta EI^s + \Delta EI^i$$  \hspace{1cm} (7)
\( \Delta EI^p \) and \( \Delta EI^l \) are calculated by the following expressions separately, where \( r_i^Q \) and \( r_i^E \) represent the growth rate of economic output and electricity consumption of city \( i \) in the period from \( t_0 \) to \( t_1 \).

\[
\Delta EI^p = \sum_i \frac{g_i^l}{q_i^t} \frac{q_i^t}{q_i^0} \ln \left( \frac{q_i^t}{q_i^0} \right) - \ln \left( \frac{g_i^l}{q_i^0} \right) - \ln \left( 1 + r_i^Q \right)
\]

(8)

\[
\Delta EI^l = \sum_i \frac{g_i^l}{q_i^t} \frac{q_i^t}{q_i^0} \ln \left( \frac{g_i^l}{q_i^0} \right) - \ln \left( \frac{q_i^t}{q_i^0} \right) - \ln \left( 1 + r_i^E \right)
\]

(9)

3. Decomposition of electricity consumption intensity of Shandong province

We use the spatial LMDI decomposition method proposed in this paper to decompose and analyze the changes of the overall electricity consumption intensity in Shandong Province from 2015 to 2018, and further investigate the differences among the cities. The detailed results are shown in Table 1.

**Table 1.** Decomposition Results of Electricity Consumption intensity in Shandong Province (KWh/ yuan, Constant prices for 2015 )

| Time interval | n=17 |
|--------------|-----|
| Initial electricity consumption intensity | 599.93 |
| Terminal electricity consumption intensity | 759.89 |
| electricity consumption intensity variation | 159.96 |
| Contribution of city’s economic growth factors (\( \Delta EI^p \)) | -7.70 |
| Contribution of city’s electricity consumption intensity factors (\( \Delta EI^l \)) | 167.66 |

Source: statistical calculations by the author.

As can be seen from the above table, in the sample of 17 cities in Shandong Province from 2015 to 2018, the electricity consumption intensity of each city (\( \Delta EI^l \)) increased the overall electricity consumption intensity of Shandong Province by 167.66 KWh/yuan (Constant prices for 2015), with the contribution level of 105.8%, which was the main factor for the increase of overall electricity consumption intensity in Shandong Province.

**Table 2.** Contribution of Each City to the Electricity Consumption intensity of Shandong Province(KWh/ yuan, Constant prices for 2015 )

| City         | Contribution of each city’s economic growth | Contribution of each city’s electricity consumption intensity |
|--------------|---------------------------------------------|----------------------------------------------------------|
| Binzhou      | -8.6390                                     | 119.5752                                                 |
| Dezhou       | -0.0637                                     | -2.1856                                                  |
| Dongying     | -1.2424                                     | 8.3140                                                   |
| Heze         | 0.9081                                      | 7.5409                                                   |
| Jining       | -0.1856                                     | -0.5201                                                  |
| Jinnan       | 0.6402                                      | -4.1776                                                  |
| Laiwu        | 0.1541                                      | -0.6791                                                  |
| Liaocheng    | -0.4428                                     | -1.9579                                                  |
| Linyi        | 0.7966                                      | 13.1935                                                  |
| Qingdao      | 0.7150                                      | 4.4794                                                   |
| Rizhao       | 0.7464                                      | 4.1838                                                   |
| Taian        | -0.4081                                     | 1.9062                                                   |
| Weifang      | 0.4753                                      | 11.8064                                                  |
| Weihai       | 0.2078                                      | 0.6317                                                   |
| Yantai       | -0.2769                                     | 12.4174                                                  |
| Zaozhuang    | -0.5749                                     | 1.3295                                                   |
| Zibo         | -0.0856                                     | -8.1929                                                  |

Source: statistical calculations by the author.
As shown in Table 2, the paper further investigates the differences among the cities that affect the increase of the overall electricity consumption intensity in Shandong Province. On the whole, the top five cities contributing to the increase of overall electricity consumption intensity in Shandong Province are Binzhou, Linyi, Yantai, Weifang, Heze, with the contribution levels of 110.9362, 13.9901, 12.1405, 11.8539, 8.4490 KWh/yuan (Constant prices for 2015). In particular, the growth of electricity consumption intensity in Binzhou is the main driving force of total intensity growth, accounting for 69.35%. However, 6 cities (Dezhou, Jining, Jinan, Laiwu, Liaocheng, Zibo) play a negative role in the rise of Shandong's overall electricity consumption intensity. From the perspective of influencing factors, the five cities that contribute the most to economic growth factor are Heze, Linyi, Rizhao, Qingdao, and Jinan. The contribution levels are 0.9081, 0.7966, 0.7464, 0.7150 and 0.6402 KWh/yuan (Constant prices for 2015); the top five cities contributing to the electricity consumption intensity factor are Binzhou, Linyi, Yantai, Weifang and Dongying, the contribution levels are 119.5752, 13.1935, 12.4174, 11.8064 and 8.3140 KWh/yuan (Constant prices for 2015). It can be seen that Binzhou plays a positive role in the electricity consumption intensity growth of Shandong Province.

4. Conclusion and Discussion

In this paper, we use spatial LMDI method to decompose the influencing factors of Shandong Province's overall electricity consumption intensity into city’s economic growth factor and electricity consumption intensity factor, and analyze the contribution of 17 cities to the overall electricity consumption intensity change in Shandong Province from these two aspects.

Through research and analysis, electricity consumption intensity of each city is the driving force of the total electricity consumption intensity growth in Shandong Province, while the city’s economic growth slightly reduces the total electricity consumption intensity. Among the 17 cities, Binzhou contributes the most to the growth of the total electricity consumption intensity; Dezhou, Jining, Jinan, Laiwu, Liaocheng, Zibo have a negative effect on the growth of the total electricity consumption intensity.

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