Study on Influencing Factors of Carbon Emission of Civil Buildings Based on Regional Differences

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Abstract. China's civil building carbon emissions show different characteristics due to different regions, so we should take measures to reduce carbon emissions according to local conditions. In this paper, LMDI model is used to study the influencing factors of carbon emissions in four regions of China according to the total amount and efficiency of carbon emissions. The influencing factors are divided into economic scale effect, per capita economic effect, urbanization effect, per capita building area effect, energy consumption per unit area effect and comprehensive carbon emission factor effect, and decompose each effect, find out the key factors that affect the carbon emissions of civil buildings in each region, and provide the direction for carbon emission governance of civil buildings in China.

1. Introduction
China is the largest carbon emitter in the world, accounting for 27.7% of the global carbon emissions, and 40% of China's carbon emissions come from buildings[1]. Therefore, reducing building carbon emissions by certain means is an important link to reduce China's carbon emissions. A large number of data show that there are obvious differences in building carbon emissions among different provinces and regions in China. At present, China's building carbon emissions have shown obvious spatial imbalance characteristics[3]. In addition to the influence of natural factors such as climate, geography and resources, the differences of social factors such as economic development, scientific and technological development, and residents' living standards also lead to differences in building carbon emissions among different regions of the country[4]. Based on the characteristics of regional differences in building carbon emissions, it is necessary to implement differentiated emission reduction measures to control building carbon emissions in different regions.

Many scholars analyze the carbon emission data of 30 provinces in China based on cluster analysis method, and divide the 30 provinces into four regions with the total amount and efficiency of building carbon emission as variables. They are high emission and high efficiency area 1, including Jiangsu, Zhejiang, Shandong, Henan, Hunan and Guangdong; high emission and low efficiency area 2, including Beijing, Hebei, Shanxi, Inner Mongolia, Liaoning, Shanghai, Guizhou, Shanxi; low emission and high efficiency area 3, including Anhui, Fujian, Jiangxi, Hubei, Guangxi, Chongqing, Sichuan and Yunnan; and low emission and low efficiency area including Tianjin, Jilin, Qinghai, Ningxia, Xinjiang, Hainan and Gansu.[3]

After the division of regions, in order to reduce carbon emissions in each region, it is necessary to master the main influencing factors of each region, and put forward targeted energy conservation and emission reduction control according to its own characteristics[5]. The purpose of this paper is to clarify the mechanism of each influencing factor by calculating the contribution of different factors in different
regions, and to provide direction and suggestions for regional provinces and cities to formulate carbon emission reduction strategies.

2. Research model and index

In order to further study the influencing factors of regional carbon emissions, it is necessary to build models and indicators. Theoretical and practical studies at home and abroad show that LMDI decomposition model has absolute advantages in practicability, operability and result expression. Therefore, this paper selects this model to analyze the influencing factors of each region.

Based on the data published in the National Statistical Yearbook, this paper selects the construction carbon emission data of 30 provinces in China in recent ten years, and decomposes the influencing factors into six factors by LMDI decomposition model: the scale of added value of tertiary industry, per capita economic scale, urbanization rate, per capita building area, energy consumption per unit area and comprehensive carbon emission factor, the formula can be expressed as formula (1) and formula (2):

$$W = \sum_i W_i$$

$$W_i = \frac{P_i}{GDP_i} \times \frac{CZ_i}{S_i} \times \frac{E_i}{E_i} \times W_i$$

The practical meanings of the symbols in the above formula are as follows:

| Symbol | Practical significance | Remarks |
|--------|------------------------|---------|
| i      | Province region code   | Value range [1, 2, 3, 4] |
| W_i    | Building carbon emissions | Energy consumption |
| GDP_i  | Industrial output value | Per capita building area |
| P_i    | Population             | Energy consumption per unit area |
| CZ_i   | Urban population       | Comprehensive carbon emission factor |
| S_i    | Building area          | Economic intensity of population |

After further calculation of building carbon emission increment and IDA decomposition, the change of building carbon emission intensity can be obtained as formula (3):

$$D_{\text{tot}} = \frac{M_{i,t}}{M_{i,t-1}} = \exp\left\{\sum_{i=1}^{L} \frac{L(M_{i,t}S_{i,t}M_{i,o}S_{i,o})}{L(M_{i,t}M_{i,o})} \ln \frac{S_{i,t}}{S_{i,o}}\right\} = D_{\text{mci}} \ast D_{\text{str}}$$

According to formula (3), the intensity change of building carbon emission from period $\sigma$ to period $t$ is decomposed into intensity effect and economic scale effect. After the comprehensive decomposition of the strength effect $D_{\text{mci}}$, the results can be obtained as shown in the formula (4):

$$D_{\text{mci}} = \exp\left\{\sum_{i=1}^{L} \frac{L(M_{i,t}S_{i,t}M_{i,o}S_{i,o})}{L(M_{i,t}M_{i,o})} \ln (TEC_i \ast TC_i \ast EM_i \ast LM_i \ast KM_i)\right\}$$

$$D_{\text{tot}} = D_{\text{str}} \ast D_{\text{tec}} \ast D_{\text{em}} \ast D_{\text{lm}} \ast D_{\text{km}}$$

Thus, the change of building carbon emission intensity can be obtained as shown in formula (5):

$$D_{\text{tot}} = D_{\text{str}} \ast D_{\text{tec}} \ast D_{\text{em}} \ast D_{\text{lm}} \ast D_{\text{km}}$$

In the formula, $L(a,b)$ is the logarithmic mean of two positive numbers $a$ and $b$, $M_{i,t}$ is the carbon emission intensity of region $i$ in $t$ period, $M_i$ is the building carbon emission intensity of all regions in $t$ period, $S_{i,t}$ is the share of regional $i$ output in total output.

The results show that there are six factors influencing the change of building carbon emissions, which are: economic scale effect, per capita economic effect, urbanization effect, per capita building area effect, energy consumption per unit area effect and comprehensive carbon emission factor effect.
3. Empirical analysis

There are differences in building carbon emissions in different regions, and the reason for the differences is that different factors have different influence on each region. Based on LMDI decomposition model, the dimensionless results of each influencing factor can be calculated by using the ring ratio form. The value of each decomposition item is less than 1 (greater than 1), which means that it promotes the decrease (increase) of building carbon emissions. Taking the effect of economic scale as an example, we decompose the effect of economic scale into the following results, as shown in the table 2:

| Age   | Area 1   | Area 2   | Area 3   | Area 4   |
|-------|----------|----------|----------|----------|
| 2009  | 0.999683 | 0.996692 | 1.002443 | 1.001192 |
| 2010  | 1.00271  | 1.006819 | 0.982399 | 1.008306 |
| 2011  | 0.998124 | 1.000248 | 1.0033   | 0.998337 |
| 2012  | 1.003852 | 0.995789 | 0.997294 | 1.003091 |
| 2013  | 1.002382 | 0.992259 | 1.001213 | 1.004191 |
| 2014  | 0.997515 | 1.003646 | 0.992831 | 1.006065 |
| 2015  | 1.004743 | 0.999502 | 0.997412 | 0.99836  |
| 2016  | 1.000503 | 1.003267 | 0.989783 | 1.006528 |
| 2017  | 1.000288 | 0.99199  | 0.99391  | 1.003842 |
| 2018  | 1.004518 | 1.008065 | 0.993164 | 0.994339 |
| Average| 1.001432 | 1.000828 | 0.995375 | 1.002452 |

The results show that the average value of decomposition number of region 3 is the smallest and less than 1, which indicates that the economic scale effect has a weak inhibitory effect on region 3, while region 1, 2 and 4 have a promoting effect but weak. Region 3 is a low emission and high efficiency area, and most of these cities are economically underdeveloped areas, and most of them are located in the central and southern regions of China. The proportion of cities and towns is relatively low. The data show that the value-added effect of the tertiary industry will bring certain building emission reduction to the region. Therefore, this region is more suitable to vigorously develop the tertiary industry economy and will not bring greater burden to the emission reduction work.

Next, we decompose the other factors respectively (for the convenience of comparison, this paper uses the reciprocal of the decomposition value of per capita economic effect for analysis) and calculate their average values in recent ten years, as shown in Table 3:

| Influence factor                          | Area 1   | Area 2   | Area 3   | Area 4   |
|------------------------------------------|----------|----------|----------|----------|
| Economic scale effect                    | 1.001432 | 1.000828 | 0.995375 | 1.002452 |
| Per capita economic effect               | 1.014988 | 1.018849 | 1.009022 | 1.013782 |
| Urbanization effect                      | 1.005869 | 1.006431 | 1.006516 | 1.005461 |
| Per capita building area effect          | 1.016269 | 1.015175 | 1.014153 | 1.017634 |
| Energy consumption per unit area effect | 0.993956 | 0.999184 | 0.994971 | 0.991552 |
| Comprehensive carbon emission factor effect | 0.981072 | 0.975464 | 0.977365 | 0.982442 |

According to the above calculation results, the influencing factors of each region are further analyzed to find the key points to control carbon emissions. The horizontal and vertical analysis of the data of the four regions are shown in picture 1 and picture 2.
On the whole, per capita economic effect, urbanization effect and per capita building area effect play an obvious role in promoting building carbon emissions, while energy consumption per unit area and comprehensive carbon emission factor effect play an obvious inhibitory role. The effect of economic scale on building carbon emissions is not obvious, and has a weak promotion effect, which is mainly due to the relatively obvious inhibition effect of region 3. This means that the per capita economic output, urbanization rate and per capita building area play a promoting role in building carbon emissions, among which the per capita building area has a higher impact on building carbon emissions, while the urbanization rate has a relatively weak promotion effect on building carbon emissions; the energy consumption effect per unit area and the comprehensive carbon emission factor effect can restrain the building carbon emissions and play a strong supporting role in building emission reduction.

From the perspective of each region, region 1 is a region with high emission and high efficiency. In region 1, the effects of promoting effect are per capita building area effect, per capita economic effect, urbanization effect and economic scale effect from large to small, and the inhibitory effect is comprehensive carbon emission factor effect and unit area energy consumption effect. Region 2 is a region with high emission and low efficiency. In region 2, the effects of promoting effect are per capita economic effect, per capita building area effect, urbanization effect and economic scale effect from large to small, and the effect of restraining effect is comprehensive carbon emission factor effect and unit area energy consumption effect. The promotion effect of per capita economic output of region 2 is significantly higher than that of other regions, including Beijing, Shanghai and
other provinces and cities with high economic benefits. However, from the perspective of the economic scale effect of the output value of the tertiary industry, the promotion effect is not obvious, indicating that the per capita economic output of region 2 is higher and the overall economic development level is relatively high. At the same time, region 2 and area 1 are both high emission areas, which reflect the promotion effect of the influencing factors, and from the side shows the relative accuracy of regional division.

Region 3 is a region with low emission and high efficiency. In this region, what is obviously different from other regions is that the effect of economic scale plays an inhibitory role, which shows that economic growth alone can promote building emission reduction. In the process of emission reduction, it is necessary to increase the number of urban population while focusing on economic growth. In region 3, the effect of promoting effect from large to small is per capita building area effect, per capita economic effect and urbanization effect, and the effect of restraining effect is comprehensive carbon emission factor effect, energy consumption effect per unit area, and economic scale effect.

Region 4 is a low emission and low efficiency area, and its influence degree of promoting effect and restraining effect is similar to that of region 1. However, there is a big difference between area 1 and area 4, which indicates that in the process of emission reduction in the future, area 4 can learn from the control measures of area 1 to a certain extent, so as to improve its building carbon emission efficiency.

4. Conclusions

In this paper, through the establishment of LMDI decomposition model of influencing factors of building carbon emissions, six major effects are formed: economic scale effect, per capita economic effect, urbanization effect, per capita building area effect, energy consumption effect per unit area, and comprehensive carbon emission factor effect. The conclusion is as follows:

(1) From the overall point of view, the influencing factors that have played a significant role in promoting building carbon emissions are per capita building area effect, per capita economic effect, urbanization effect and economic scale effect from large to small, among which the economic scale effect is extremely weak; the comprehensive carbon emission factor effect and energy consumption effect per unit area play an obvious inhibitory role, and the inhibition effect of comprehensive carbon emission factor is greater.

(2) In terms of the degree of influence, the economic scale effect has the most obvious promotion effect on region 4, and has inhibitory effect on region 3; the per capita economic effect has a promoting effect on all regional building carbon emissions, the most obvious promotion effect is on region 2, and the promotion effect on region 3 is relatively weak; the promotion effect of urbanization on region 2 and region 3 is relatively large; the per capita construction effect is relatively large; per capita building area effect has the most obvious promotion effect on area 4; the energy consumption effect per unit area has an inhibitory effect on building carbon emissions in all regions, and the inhibition effect on area 4 is the most obvious; the comprehensive carbon emission factor effect has the most obvious inhibitory effect on region 2.

Through the research, each region should work according to local conditions, strengthen the collaborative management between provinces, improve the building energy saving and emission reduction technology, and improve the building energy efficiency, so as to obtain a stronger emission reduction effect.

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