Research on carbon emission driving factors of China's provincial construction industry

Mei SHANG\textsuperscript{1}, Rui DONG\textsuperscript{2}, Yujie FU\textsuperscript{3}, Wentao HAO\textsuperscript{4}

\textsuperscript{1,2,3,4}School of Management, Xi’an University of Science and Technology, Xi’an Shaanxi, China
\textsuperscript{1}940615683@qq.com, \textsuperscript{2}1050464068@qq.com
\textsuperscript{3}1301487417@qq.com, \textsuperscript{4}923445966@qq.com

Abstract. As a pillar industry of the national economy, the damage to the environment by construction industry can not be ignored. In the context of low carbon development, identifying the main driving factors for the carbon emission of the provincial construction industry are the key for the local government to formulate the development strategy for construction. In the paper, based on the Kaya factor decomposition method, the carbon intensity of the energy structure, energy intensity and the impact of the construction output on the carbon emission of provincial construction industry are studied, and relevant suggestions for low carbon development of provincial construction industry are proposed. The conclusion of this paper provides a theoretical basis for the early realization of low-carbon development in China’s provincial construction industry.

1. Introduction
With the continuous development of the construction industry economy, energy consumption and carbon emission are also increasing, resulted in the provincial construction industry to develop the regional economy at the expense of the environment. According to the IPCC’s fourth assessment analysis, the construction industry is not only big in energy consumption, but also carbon dioxide emissions accounted for nearly 36% of the whole society. It is crucial to find out the main drivers of carbon emissions in order to realize low-carbon development of construction industry. The need of practice promotes the development of theory. Foreign scholar Bengochea-Morancho and so on find that specific economic situation and the industrial structure of the EU member states can control the reduction of carbon emissions rather than the unified policy\cite{1}. S. Malla and so on find that the key factors to reduce carbon emissions are energy structure and energy consumption intensity, and the effects of these factors are constantly changing\cite{2}. Domestic scholar Hu Ying and ZHU Dajian analyze the main factors affecting CO\textsubscript{2} emissions from construction industry using LMDI decomposition model with relevant policy recommendations are put forward accordingly\cite{3}. Song Deyong find scale of production, energy efficiency and carbon emission intensity and the intensity of energy consumption are the main factors influencing carbon, specially the emission scale of production, energy efficiency used two-stage LMDI decomposition method\cite{4}. LI Yanmei and so on\cite{5} and CHEN Wanlong\cite{6} decomposes the influencing factors of carbon dioxide emissions with carbon structure decomposition model and Kaya formula respectively.

It is obvious, domestic and foreign scholars have more extensive research on the influence factors of carbon emission. From the perspective of research, there are national, provincial and industrial
perspectives. From the research method, there are LMDI factorization and Kaya formula. However, there are still some shortcomings in the study on the driving factors of carbon emissions in construction industry. First, the study of indirect carbon emissions in construction industry is less. Secondly, the comparative analysis of the driving factors of provincial carbon emission is also less. This is the opportunity of this study. In the paper, on the basis of considering the indirect carbon emission from buildings industry, the Kaya formula is used to analyze the driving factors of carbon emission in the provincial construction industry and provide a theoretical basis for the selection of low-carbon development path of the provincial construction industry.

2. Model selection and establishment
At present, the main methods for scholars to study the influencing factors of a variable include structural decomposition method (SDA) and Index decomposition method (IDA). Among them, the theoretical derivation of SDA is simple and rigorous, and the data is clear. It can make a reasonable analysis of the direct and indirect factors in a more accurate level. SDA has the advantage of being able to analyze the direct and indirect influences through the input-output model. The disadvantage of SDA is that it relies on the data of input-output table issued by the country to make its application be bound. IDA begin in the 1970s, and later scholars expand it, derive a simple average decomposition method (SAD), logarithmic mean weight decomposition method (LMDI), Kaya identity method\(^7\). The basic idea of IDA is to measure carbon emissions with the weighting of several major factors. In this paper, the influence factors of carbon emission are studied, and the Kaya formula is more applicable.

The Kaya formula was proposed at the IPCC seminar in 1989 by Prof. Yoichi Kaya in Japan. The main idea is to express the economic, policy, population and other factors and the \(\text{CO}_2\) emissions produced by human activities in a simple formula. See formula (1)

\[
\text{CO}_2 = \frac{\text{CO}_2}{\text{PE}} \times \frac{\text{PE}}{\text{GDP}} \times \frac{\text{GDP}}{\text{POP}}
\]

In which: \(\text{CO}_2\) refers to total carbon dioxide emissions. \(\text{PE}\) refers to the total amount of primary energy consumption. \(\text{GDP}\) refers to gross domestic production. \(\text{POP}\) represents the total population of the country. \(\text{CO}_2/\text{PE}\) is called carbon intensity of energy structure. \(\text{PE}/\text{GDP}\) is the energy intensity of unit production. \(\text{GDP}/\text{POP}\) represents per capita gross domestic product.

In this paper, The analysis ideas of Kaya identity are introduced into the low-carbon study of construction industry. Then, \(\text{CO}_2 / \text{PE}, \text{PE} / \text{GDP}\) and gross output value of construction industry affecting construction carbon are brought into the identity. See formula (2)

\[
\text{CO}_2 = \frac{\text{CO}_2}{\text{PE}} \times \frac{\text{PE}}{\text{GDP}} \times \text{GDP}
\]

In which: \(\text{CO}_2\) refers to total carbon dioxide emissions(The unit is 10000 tons). \(\text{PE}\) refers to the total energy consumption of construction industry(The unit is 10000 tons). \(\text{GDP}\) refers to the gross output value of the construction industry(The unit is 10000 tons).

\(\text{CO}_2/\text{PE}\) represents carbon intensity of energy structure, that is, the carbon energy generated by the unit energy consumption. The smaller the value it means, the better the application of the emission reduction technology. On the contrary, the emission reduction technology needs to be further improved. Without considering the updating of the technological level, the condition of energy structure is the main factor affecting the carbon intensity of the energy structure.

\(\text{PE}/\text{GDP}\) represents the energy intensity of unit production. The value reflects the economic benefits of energy consumption. The smaller the value, the higher the economic benefits of energy and vice versa. The improvement of energy intensity of unit production value is mainly from two parts, One is the progress of industrial technology and the elimination of backward industries with high energy consumption; the other is from low value-added to high value-added parts in the industrial chain.

First, the right and left sides of the equation (2) are simultaneously taken into logarithms, and then differential operations are performed, after equivalent transformation and arrangement, see formula (3)
\[ d(\ln CO_2) = d(\ln \frac{CO_2}{PE}) + d(\ln \frac{PE}{GDP}) + d(\ln GDP) \]  

(3)

In which: \(d(\ln CO_2)\) represents the total intensity of carbon emissions. \(d(\ln \frac{CO_2}{PE})\) represents carbon intensity effect of energy structure. \(d(\ln \frac{PE}{GDP})\) represents energy intensity effect of per unit production value. \(d(\ln GDP)\) represents output size effect. Based on formula (3), the main influencing factors of carbon emission in provincial construction industry are analyzed.

3. The empirical analysis

In this paper, according to the characteristics of construction industry and the availability of data, the total emission of \(CO_2\), the total energy consumption of construction industry( calculated by standard coal) and the economic output value of construction industry are selected to analyze the factors influencing the carbon emission of provincial construction industry.

3.1. Calculation of energy consumption and carbon emission in provincial construction industry

The total energy consumption data of the provincial construction industry is derived from statistical yearbook, include direct and indirect energy consumption in the construction industry (Figure 1). According to the total energy consumption of the construction industry and the carbon emission coefficient of various energy sources, the total carbon emission of the provincial construction industry can be calculated (Figure 2).

3.2. Analysis on the influence factors of carbon emission in provincial construction industry

According to the total energy consumption and carbon emission of the provincial construction industry from figure 1 and 2, the influence factors of carbon emission of provincial construction industry in China are analyzed by using formula (3) and (4). And then energy intensity effect of per unit production value, carbon intensity effect of energy structure, and the change of carbon emission caused by the intensity effect of production are calculated(Figure 3).

Figure 1. Provincial total energy consumption of construction industry in 2005-2014

Figure 2. Total carbon emissions of provincial construction industry in 2005-2014

Figure 3. The influence of the influence factors of carbon dioxide emission in the provincial construction industry in 2005-2014
4. Conclusions
As can be seen from Figure 3, the average annual growth rate of CO₂ emissions in China's construction industry in the past ten years is quite different. Among them, Beijing and Shanghai showed negative growth, but the average annual growth rate of carbon emissions of other 28 provinces is positive. Therefore, it is necessary to promote low carbon and zero carbon building materials while pursuing the development of the construction industry. The production value of construction industry plays a positive role in carbon emissions, while carbon intensity of energy structure and energy consumption intensity of per unit production value are the main factors affecting carbon emissions. However, the influence degree of each province is different, among which energy consumption intensity has the greatest impact on carbon emissions in the economically underdeveloped areas.

4.1. Analysis of the impact of carbon intensity of energy structure on carbon emission
From Figure 4, the carbon intensity of the energy structure in the provincial construction industry changed greatly from 2005 to 2014. Among them, the lowest of Hebei is -0.47 in 10 years. Besides, in addition to the positive value of the two years from 2009 to 2011 in Hebei, the rest is negative. It shows that the development and popularization of new low-carbon energy resources in Hebei are better in recent years. The change of influencing factors in Jiangsu province is very similar to that in Hebei province. Emphatically, from Figure 4, As can be seen, from 2005 to 2014, the impact of carbon intensity of energy structure on carbon emissions is the biggest change in Beijing. The impact is most obvious between 2010 and 2011. Trace its root, Beijing's energy consumption change to negative 1.11 and the change in carbon dioxide is negative 0.71, that means Beijing's carbon dioxide emissions and energy consumption are decreasing, while energy consumption is also falling. This situation reflects the energy saving and emission reduction of Beijing construction industry has been improved, and its energy conservation is much more obvious than the carbon emission reduction. In Jilin province, the influence of carbon intensity of energy structure on carbon emissions is constantly transformed between positive and negative effects from 2005 to 2014, but the overall impact is negative. It is indicated that the carbon intensity of the energy structure of Jilin's construction industry is changing obviously with the economic development, and the popularization of new energy is needed. In general, the impact of Beijing's and Jilin's carbon emissions are outstanding, in construction industry of other 28 provinces, the influence of carbon intensity of energy structure on carbon emission is between minus 1 and positive 1, and the fluctuation is not great. It shows that the overall low carbon level of China's construction industry is not high and needs to be improved in terms of energy utilization and energy structure.

4.2. Analysis of the influence of energy intensity on carbon emission
From Figure 5, from 2005 to 2014, the impact of energy intensity on carbon emissions in the provincial construction sector varies greatly, and the contribution value varies every year. Among them, the energy intensity of Beijing's per unit production is the most obvious, in addition to the positive impact on carbon emissions from 2008 to 2009, the other eight years have contributed negatively to carbon emissions. The changing trend in Shanghai is similar to that in Beijing. Thus, for Shanghai and Beijing provinces, not only the improvement of industrial technology is explained, but the elimination of backward high energy consuming building equipment is also explained. And then energy has changed from low value-added to high added value in the construction industry chain. Besides, the energy intensity shows integrally a negative contribution to carbon emissions, which shows that the economic benefits brought by energy saving technology are better. Such as Inner Mongolia, Liaoning, jilin, Shandong and other provinces. On the contrary, from 2005 to 2014, Xinjiang's energy intensity is always in the positive contribution between 0 and 0.1. And then three results are illustrated accordingly. First, the construction industry in Xinjiang is a high energy consuming industry. Second, the value-added conversion rate of energy is very low. Third, the industrial technology level is not advanced. Overall, the construction industry in China's southwest and northwest regions is low in low-carbon technology, energy equipment is not advanced, and energy-saving technologies need to be
improved greatly.

**Figure 4.** The influence of carbon intensity of energy structure on carbon emission

**Figure 5.** The influence of energy intensity effect of per unit production value on carbon emission

**Figure 6.** The influence of production value on carbon emission

4.3. **Analysis of the impact of construction production on carbon emissions**

From Figure 6, the GDP impacts of the provincial construction industry all show positive contribution to carbon emissions, and there is little difference in each province, basically around 0.1, so China's provincial construction economy is in a healthy stage of development and its status in regional economic development is becoming more and more important. However, obviously, carbon emissions in each province vary over the years from 2005 to 2014, especially in Inner Mongolia, Tianjin, Shanxi and other provinces change a lot. This is also the necessity of this paper to study the provincial construction industry.

**Acknowledgments**
The paper is supported by National Science Project (71273207).

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