Drivers and mitigation implications of carbon emissions from the direct energy consumption of Gansu's construction industry

Lele Xin¹², Junsong Jia¹²* and Xu Song¹²

¹School of Geography and Environment, Jiangxi Normal University, Nanchang, Jiangxi, JX 791, China
²Key Laboratory of Poyang Lake Wetland and Watershed Research, Ministry of Education, Jiangxi Normal University, Nanchang, Jiangxi, JX 791, China
*Corresponding author’s e-mail: jiaaniu@jxnu.edu.cn

Abstract. More and more carbon emissions (CE) were produced and arose from the direct energy consumption in Gansu's construction industry. So, we first computed the CE of Gansu's construction industry during 2000–2017 in this paper, and then used the Logarithmic Mean Divisia Index (LMDI) model to decompose the driving factors of CE. The results showed that: (1) the CE of Gansu's construction industry increased from 95.44×10⁴ t in 2000 to 127.84×10⁴ t in 2017, with the annual growth amount of 1.91×10⁴ t and rate of 2%, respectively. (2) The economic development level effect was the dominant driver to promote the CE of Gansu’s construction industry followed by the employment population effect, with the contributions of 100.61×10⁴ t and 44.03×10⁴ t. However, the energy intensity effect played the most primary role in inhibiting the CE growth, which followed by the energy structure effect, with the contributions of -107.25×10⁴ t and -4.99×10⁴ t, respectively. Based on the above conclusions, some mitigation implications for the low-carbon development of Gansu's construction industry were put forward.

1. Introduction

The construction industry plays an important role in the process of economic construction and urbanization development. At present, the greenhouse-gas emissions from the energy consumption of construction industry account for one-fourth of the total greenhouse-gas emissions in China, and about one-third of the social consumption come from the construction industry[1]. Therefore, it is necessary for us to research the carbon emissions (CE) and the corresponding driving factors in the construction industry. Meanwhile, the Logarithmic Mean Divisia Index (LMDI) has become the most popular method because of its incomparable advantages[2] and was used by many scholars. For example, Fan, et al.[3] used the LMDI method to decompose the CE of China's construction industry from 1997 to 2015 based on the CE of construction industry in 30 provinces.

In recent years, in order to achieve energy conservation and emission reduction targets, Gansu proposed to strengthen energy conservation in construction industry during "13th Five-Year Plan" for controlling greenhouse-gas emissions[4]. Thus, to achieve this target, it is indispensable to analyze the CE of Gansu's construction industry and decompose its influencing factors, so as to propose the scientific carbon reduction strategy.
2. Data and methods

2.1. Data sources
The data, including the relevant economy and population number and various energy consumption of Gansu's construction industry, are all derived from the Gansu Development Yearbook (2000-2017).

2.2. Methods

2.2.1. Computing method of carbon emission.
In this paper, we adopted the widely used method provided by the Intergovernmental Panel on Climate Change[5], which was listed as the following equation (1):

\[ C = \sum_{j=1}^{7} C_j = \sum_{j=1}^{7} E_j \times f_j \]  

Where: \( C \) denotes the total CE of construction industrial energy consumption, \( j \) denotes the energy type, \( E_j \) denotes the consumption of \( j \) energy, \( f_j \) denotes the carbon emission coefficient of energy \( j \), and it was estimated based on the carbon content, carbon oxidation rate, and net calorific value provided by IPCC.

2.2.2. The extended LMDI model.
The extended LMDI procedure is from the article[5].

3. Results and analysis

3.1. Empirical analysis of the direct CE in Gansu's construction industry
As shown in Figure 1, since the Western Development Strategy was implemented in 2000 year, the gross output value of Gansu’s construction industry has rapidly grown from 126.40×10^8 yuan in 2000 to 415.90×10^8 yuan in 2017, with an increasing amount of 289.50×10^8 yuan and an average annual growth rate of 7%. With the rapidly increasing rate of gross output value in construction industry, the energy consumption increased from 38.74×10^4 t in 2000 to 46.5×10^4 t in 2017, with an average annual growth rate of 1%. Meanwhile, the CE also showed a whole upward trend in fluctuation with the fluctuating increase of energy consumption. The CE increased from 95.44×10^4 t in 2000 to 127.84×10^4 t in 2017, with a growth rate of 34% and an average annual growth rate of 2%. On the whole, the CE rose slowly in the early period, and rapidly increased in the mid-term. However, it experienced a fluctuating change in the later period. The specific changes were as follows: during 2000-2008, the CE grew slowly, with a growth rate of 10.11%. But it rapidly grew from 2009 to 2013, with a growth rate of 40%. One reason might be the large-scale infrastructure construction in order to restore economic development after the 2008 financial crisis. Another reason might be that the proportion of urban population rapidly increased from 32.65% in 2009 to 40.13% in 2013, which led to the CE increase with the growth of demands for urban housing and infrastructure. Compared with the previous period, the CE experienced a fluctuating change during 2014-2017. The main reason was that the proportion of carbon-intensive fuels used like raw coal was fluctuating.
3.2. Decomposition results and analysis

According to Formula (1), the energy structure effect, energy intensity effect, economic development level effect and employment population scale effect of direct CE in Gansu’s construction industry during 2000-2017 were calculated as shown in Figure 2.

The energy intensity effect was the main driving factor of reducing the CE of Gansu’s construction industry. It can be seen from Figure 2 that the cumulative effect of energy intensity was -107.25×10^4 t during 2000-2017. Namely, the inhibitory effect of CE largely depended on the decrease of energy intensity. From 2000-2017, the energy intensity of construction industry decreased from 0.31t/10^4 yuan to 0.11t/10^4 yuan, with an annual changing rate of -6%. This could be explained by the continuous innovation of construction technology and improvement of energy efficiency. In a long run, energy efficiency will still be the primary contributor to mitigate the CE of construction industry. With the continuous improvement of the energy-saving measures and regulations in construction industry, the contribution of energy intensity to the reduction of CE will continue to increase.

The energy structure had the weakest mitigating effect on the CE of Gansu’s construction industry, and it contributed -4.99×10^4 t (Figure 2). This result showed that the adjustment of energy structure had a minor impact on carbon emission reduction. From the perspective of seven type’s energy consumed by the construction industry, coal, diesel and gasoline were the major types of energy consumption in construction industry. However, the proportion of coal showed a decreasing trend. It decreased slightly from 57.74% in 2000 to 36.56% in 2017. Although the proportion of coal has declined in recent years, it still played a dominant role in Gansu’s construction industry. Therefore, the adjustment of the energy consumption structure can't be ignored in construction industry for a long time.

The economic development level effect was the leading factor in promoting CE growth during 2000-2017, with a cumulative contribution was 144.64×10^4 t. The gross output value of Gansu’s construction industry increased from 126.40×10^8 yuan in 2000 to 415.90×10^8 yuan in 2017, with an average annual growth rate of 7%. The increasing trend of CE was roughly similar with that of gross output value. That is to say, Gansu's economy has made great achievements due to the implementation of the Silk Road Economic Belt and the Western Development Strategy. Therefore, the industrialization and urbanization of Gansu are also developing rapidly. As we all know, the rapid urbanization is accompanied by the continuous rise of real estate boom and the expansion of urban construction land, which leading to the increase of the energy demand and CE.

The employment population scale effect also had the positive effect on promoting CE growth, and it totally contributed 44.03×10^4 t to CE during 2000-2017 (Figure 2). With the vigorous expansion of construction scale, the employment population in the construction industry has increased. During 2000-2017, the number of construction workers increased from 33.17×10^4 persons to 48.6×10^4 persons, with
an average annual growth rate of 2%. It meant the demand of urban housing and infrastructure construction had increased, thereby promoting the increase of CE in the construction industry.

4. Conclusions and policy implications
The direct CE of Gansu’s construction industry showed a whole upward trend in fluctuation with the fluctuating increase of energy consumption. The CE increased from $95.44 \times 10^4$ t in 2000 to $127.84 \times 10^4$ t in 2017, with an increasing rate of 34%. Then, the effect of economic development level was the dominant driver of promoting the CE growth of Gansu’s construction industry, followed by the employment population effect. However, the energy intensity effect, played the primary role in inhibiting the growth of CE, which followed by energy structure effect.

Thus, the following countermeasures could be put forward to promote the low-carbon development of Gansu’s construction industry. First, we should adjust the energy consumption structure. The energy consumption structure of the construction industry was still dominated by coal in Gansu. So, in the future, the proportion of coal, gasoline and diesel should be reduced, and the proportion of natural gas and clean energy should be increased. Second, the energy intensity effect had a significant inhibitory effect on the CE growth of the construction industry. Therefore, it is important to improve the efficiency of energy use, to make the best use of recyclable building materials and strengthen green construction, and to apply energy-saving facilities, new materials and technologies to the construction site to reduce the energy intensity. Third, the government should strengthen the legislative work, improve the legal system, carry out strict supervision and management, rectify the construction projects that do not meet the energy-saving standards, and raise awareness of energy conservation and emission reduction among the employment population.

Acknowledgments
We are very grateful for the financial support provided by the Research Project of Humanities and Social Sciences in Jiangxi’s Universities (Grant No. GL19225) and Chinese National Science Foundation (Grant No. 71473113).

References
[1] Lu, J.C., Zhong, Z., Huang, X.X. (2017) Evolution Characteristics of Carbon Emission in China's Construction Industry and Decomposition of Influencing Factors with LMDI. J. Construction economy., 38: 81-88. (In Chinese)
[2] Ang, B.W. (2004) Decomposition analysis for policymaking in energy: which is the preferred method?. J. Energy Pol., 32: 1131-1139.
[3] Fan, J.S., Zhou, L. (2019) Spatiotemporal distribution and provincial contribution decomposition of carbon emissions for the construction industry in China. J. Resources Science., 41: 897-907. (In Chinese)
[4] The Government of Gansu Province. (2017) Notice of the People's Government of Gansu Province on issuing the Implementation Plan for the Control of Greenhouse Gas Emissions during the 13th Five-Year Plan of Gansu Province. http://www.gansu.gov.cn/art/2017/2/13/art_4785_300006.html.
[5] IPCC. (2006) Energy. In: Eggleston, H.S., Buendia, L., Miwa, K. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IGES, Paris. pp.11-13.