



# Examining the effects of urbanization and industrialization on carbon dioxide emission: Evidence from China's provincial regions



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## ABSTRACT

With rapid economic development and expansion of built environment since the year 2000, urbanization has led to great challenge of reduction targets in energy intensity and carbon dioxide emissions. This paper aims to explore the disaggregate driving force of different sectors and investigate the potential of carbon dioxide reduction of them in the context of rapid urbanization. By using the panel datasets at a provincial level in a LMDI (Logarithmic Mean Divisia Index) model, we investigated the effects of various energy-related and socioeconomic factors on regional carbon dioxide emissions in 30 China's provinces from 2000 to 2013. The results show that the factors of economic development are the largest drivers of regional carbon dioxide emissions, compared with the factors of structural change, energy intensity, and social transition. Meanwhile, evidence is found that the urbanization process has contributed to the regional CO<sub>2</sub> emissions in China's provinces through a variety of approaches, including changing the energy use characteristics of urban households, transportation, and business sectors. Finally, we found that the changing trend of these influence factors' effect on regional CO<sub>2</sub> emissions varied across different provinces, which means there are significant regional heterogeneity in the influence mechanisms of urbanization process on regional CO<sub>2</sub> emissions.

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## 1. Introduction

With rapid economic development and expansion of the built environment, urbanization has taken place at an unprecedented rate in China since the year 2000. The proportion of the Chinese population living in urban areas reached 56% in 2015, whereas it was only 36% in 2000 [16]. Rapid urbanization and industrialization propelled huge economic growth, which was also accompanied by severe increase in fossil energy demand and carbon dioxide emissions.

The relationship between urbanization and regional CO<sub>2</sub> emissions has been extensively discussed in the field of energy consumptions and energy-related emissions. Some basic conclusions regarding the impact of urbanization on energy consumption and regional CO<sub>2</sub> emissions has been made. Generally, most studies confirm that urbanization and industrialization have significant

influence on energy consumption and carbon emissions [1,12,17,18,22]. Additionally, some recent literature has shown mixed results about the relationship between urbanization and energy consumption, which means the influence effects of urbanization and industrialization on energy use vary at different development stages and in different regions [12,15]. Although the influence effects of urbanization on energy use and CO<sub>2</sub> emissions are generally positive, increasing studies argue that a couple of factors within urbanization process may create potential for the reduction of energy demand.

Consequently, the mechanism how urbanization process influences energy consumption and CO<sub>2</sub> emission is dynamic and complex involving both positive and negative effects. In order to investigate the underlying mechanisms, we need to dig into the micro-foundation of urbanization influence on energy use and emissions. First, the changes in regional CO<sub>2</sub> emissions related to differing industrial and residential sectors are influenced differently by urbanization processes, for example, urbanization may raise the energy use in urban households but reduce that in the local agricultural sector. Furthermore, from a dynamic view, the

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energy-related emissions in certain sectors may change their trends to be decrease because of technological developments. Understanding the underlying drivers of emission changes in fundamental sectors may help policy makers to adjust industrial policies to limit the incremental environmental damage associated with the rapid economic growth. However, the studies regarding the different effect of urbanization on energy use in various sectors are rather limited [15,22,26].

Another major shortcoming of existing literature is that regional heterogeneity has been scarcely taken into consideration in the discussion of urbanization and regional CO<sub>2</sub> emissions [30]. There is a huge difference in population, economic development level, urbanization level, energy efficiency and other indicators in different regions of China [11]. And the heterogeneity of energy consumption patterns and the urbanization process among provinces in China is widely recognized by analysts [15]. Thus there is a necessity for the energy and environmental policy makers to understand the regional differences in the dominant driving forces of regional CO<sub>2</sub> emissions and the locus of potential opportunities for CO<sub>2</sub> emissions reduction.

This paper provides novel insights to the mechanisms of urbanization influence on regional CO<sub>2</sub> emissions by the following: 1) clarifying and comparing the contributions of industrial sectors, residential sectors, economic development, and social transition to regional emissions; 2) depicting the dynamic changes in the effect of different types of driving forces on regional CO<sub>2</sub> emissions; 3) analyzing the regional heterogeneity in influence mechanisms of urbanization on regional emissions; 4) providing policy implications for regional low-carbon development according to the research findings.

## 2. Literature review

A growing body of literature ties urbanization to energy use and carbon dioxide emissions. In general, both positive and negative effects of urbanization on carbon dioxide emissions are found in a variety of studies. For example, many studies confirm a positive correlation between urbanization and carbon dioxide emissions in a cross-country context by adopting cross-country panel data analysis [4,8,12,13,15], while some other research found a negative influence of urbanization on the energy consumption of developed countries [1]. Therefore, the existing literature of relationships between urbanization and carbon dioxide emission is incoherent.

Especially, in the strand of the studies that focus on causal effect of socioeconomic growth on energy use and carbon dioxide emissions in China, consensus either on the existence or on the direction of the causal relationship has not been produced [23,26]. This is partly due to differences in methods and sample data, but also reflecting the complex influences of urbanization on energy consumption and carbon dioxide emissions [12]. Thus, recent studies have increasingly focus on the mechanism or key factors of urbanization influence on energy use and carbon dioxide emission.

According to the previous research, urbanization can impact energy use and emissions through multiple channels: transforming production [14,26], changing consumer behavior [31], providing public infrastructures and influencing transport service [15,16]. The key point is that the characteristics of urbanization effect on carbon dioxide emissions vary across different industrial sectors of an economy. In other words, there are mixed effects of urbanization on energy use and carbon dioxide emissions. For example, although

public infrastructure like central heating increases the energy use by urban residents, it also create potential for reducing energy demand in urban areas [26], because some technological measures including energy-saving buildings, central heating systems improve energy efficiency [15]. Besides, urban dwellers with enhancing awareness of energy-saving may shift their consumption patterns towards green products [28]. What's more, even though the industrial production process in cities gives rise to enormous energy consumption, the compact city theory argues that high urban density allows cities to exploit economies of scale for urban public infrastructures by reducing car dependency, travel distance, the transmission and distribution losses of electricity supply, together resulting in a reduction of energy consumption [15,26].

The decomposition analysis, furthermore, allows researchers to investigate the socioeconomic driven forces of carbon dioxide emission, which offers clues of low-carbon development policies. Most of them confirm that the main influencing factors are energy intensity, energy mix, gross domestic product structure, and GDP itself [3,4,10,22,30,32,33]. Wang et al. [19] decomposed the carbon emissions into population, GDP per capita, energy consumption intensity and energy consumption structure and concluded that the total theoretical decrease of CO<sub>2</sub> emission from 1957 to 2000 can be attributed to fossil fuel mix and renewable energy penetration. Besides, some studies argued that the reduction in CO<sub>2</sub> emissions can be attributed to the reduced energy intensity and fuel switching and renewable energy penetration. Meanwhile, some researches attached great importance to the adjustment of industrial structure for the process of developing low-carbon emission industries [14,21,24].

The current analysis of the mechanism or key factors of urbanization influence on energy use and carbon dioxide emission, however, is inadequate. The reason is that the effect of different industrial sectors on carbon dioxide emissions is significantly asymmetrical, meanwhile urbanization process leads to different changes in these sectors. In other words, only have the distinguished contributions of various sectors on CO<sub>2</sub> emissions been discovered and compared empirically, could we explain how urbanization triggers changes in the energy use in the key sectors, which in turn affect regional carbon dioxide emissions.

Another cause of different urbanization influence on carbon dioxide emission is regional heterogeneity [11]. However, the studies on the urbanization effect on energy-related CO<sub>2</sub> emission in Chinese provinces are incomplete and fragmented. This fragmentation likely stems from the fact that researchers are interested in a broad range of specific questions in particular research contexts and have tackled a variety of sector-specific [6,9,17,18,25,27] and region-specific research [17,18,21,24,32,33], for example, the carbon emission trading in Guangdong Province [20], the energy efficiency in Shandong Province [7], and the industrial restructuring in Jiangsu Province [29]. The fragmented research landscape raises up many fundamental questions for scholars of this field. During the rapid urbanization process, which industrial sector in which region has performed significant changes in terms of contributing to regional carbon dioxide emissions? How does urbanization effect on carbon dioxide emissions vary across the regions in China? What are the reasons for the regional heterogeneity of urbanization effect on CO<sub>2</sub> emissions?

From the practical perspective, regional heterogeneities play important role in making regional low-carbon policies. That is because there is a huge difference in population, economic development level, urbanization level, energy efficiency and other

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