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The effects of transportation infrastructure on urban carbon emissions

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HIGHLIGHTS

- We explore the effects of transportation infrastructure on urban carbon emissions.
- We use an improved STIRPAT model to analyze effects of transportation infrastructure on urban carbon emission by city scale.
- We analyze channels through which transportation infrastructure affects emissions.
- Transportation infrastructure increases urban carbon emissions and intensity.

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ABSTRACT

Against the background of global warming, China faces the dual pressures of economic structural transformation and carbon emission reduction. While promoting economic development, the development and construction of transportation infrastructure has contributed to urban carbon emissions. Using an improved STIRPAT model, we examine panel data for 283 cities between 2003 and 2013 to explore the effects of transportation infrastructure on urban carbon emissions. The results show that transportation infrastructure increases urban carbon emissions and intensity. In addition, while the population scale effect of transportation infrastructure is conducive to decreasing carbon emissions, the economic growth and technological innovation effects of transportation infrastructure increase carbon emissions. Results also demonstrate that in large and medium-scale cities, construction of transportation infrastructure increases carbon emissions. In small cities, this relationship is not significant. Robustness tests support all findings. These results indicate that the effective development of carbon-abatement policies requires an examination of the effects of transportation infrastructure.

1. Introduction

Global greenhouse gas emission is the main cause of global warming. As a result, many countries have sought to simultaneously control the emission of greenhouse gas and improve the nature of their economic development. As the world's largest developing country, China's rapid economic development has resulted in an increase in carbon emissions. In 2013, China accounted for roughly one-third of total global carbon emissions, emitting about 10 billion tons.[1] Currently, China is restructuring its economy while attempting to maintain a low carbon footprint. In response to the demand associated with this efforts, the Chinese government has avowed to decrease its carbon emission intensity by 60–65% (relative to 2005), and achieve peak emissions by around 2030. In addition, the outline of the National Economic and Social Development Plan for 2016–2010 calls for a reduction in carbon emissions such that China reduces the volume and intensity of its emissions.

Urban areas contain 40% of the Chinese population and contribute 75% of the Chinese national economy [1]. As such, these urban areas are critical for the economic success of China. However, there remains a need to reduce carbon emissions in these areas. One factor that affects carbon emissions in urban areas is the construction of transportation infrastructure. The development of this infrastructure reduces transportation costs and transit time, and promotes inter-regional communication. It facilitates the expansion of regional markets and population, which is necessary to promote regional economic growth and technological improvements. Despite these benefits, the construction of transportation infrastructure has affected urban carbon emissions. To achieve salient goals related to reducing carbon emissions, it is necessary to

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[1] These data are from the World Bank.

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examine the effects of transportation infrastructure on urban carbon emissions and whether these effects vary by city scale.

Despite the importance of this line of research, there has been little scholarship to examine the relationship between transportation infrastructure and carbon emissions. Some scholars have studied the influence of transportation on carbon intensity, the factors that drive transportation carbon emissions, and the carbon performance of the transportation industry. Construction associated with local transportation increases the carbon intensity of not only the province in which the construction occurs, but the neighboring provinces as well [2]. Extant research on the antecedents of transportation carbon emissions indicates that economic growth exerts a positive effect carbon emissions. In contrast, market concentration, population density, and transportation intensity effects reduce carbon emissions [3–5]. Additionally, researchers have also studied the carbon performance of the transportation industry. These studies have produced inconsistent results. Some scholars believe that the carbon performance of China's transportation shows a downward trend [6], because of the technological decline [7]. Others, however, have argued that the total factor carbon emissions performance of China's transportation industry has increased as a function of technological innovation [8].

Researchers have primarily utilized index composition analysis (IDA), structural decomposition analysis (SDA), and the STIRPAT model to examine factors that influence carbon emissions. IDA was first extended from energy consumption to energy-related carbon emission studies in 1991 [9]. Since the expansion of IDA, most studies have used the logarithmic mean Divisia index (LMDI) method to investigate carbon emission [10]. These studies have shown that in China, whereas the industry has led to an increase in carbon emissions, improvement in energy and electricity intensity can reduce emissions [11,12]. Other studies have shown that industrial activity and energy intensity are key factors in reducing carbon emissions [13,14].

The SDA method is a popular decomposition technique used to identify the factors that drive carbon emissions. SDA relies on the I-O (input-output) model framework to analyze the contributors of carbon emissions [15]. Researchers use an Australian input-output table to analyze the factors that affect changes in greenhouse gas emissions. This line of research has demonstrated that industrial structure change is the main driver of carbon emissions [16]. Some scholars have specifically used SDA to study the drivers of carbon emissions in China. These researchers have empirically demonstrated that production structure and population scale positively influence carbon emissions in China, while carbon intensity and GDP per capita negatively affect emissions [17]. Some scholars have also used the SDA method to perform multi-region comparisons of carbon performance [18].

Although extant research featuring the use of the IDA and SDA methods provides useful insight into carbon emission, both methods have notable limitations. The IDA method has historically allowed for the consideration of only a handful of factors: GDP per capita, energy intensity, energy consumption, and industrial structure. Because the SDA method relies on the I-O model to decompose changes in carbon emissions, it is restricted by I-O tables. This limits the scope of analyses to which the SDA method can be applied. Using the STIRPAT model may be superior to both the IDA and SDA methods. The STIRPAT model allows for the examination of more factors than IDA, and is less constrained by data than the SDA. Given its scope and flexibility, the STIRPAT model is a popular method for studying the factors that influence carbon emissions.

In recent years, many researchers have used the STIRPAT model to investigate carbon emissions. Some have shown that global population change is strongly and positively associated with carbon dioxide emissions [19]. Further, some research has shown that the effect varies at different levels of income [20]. Evidence from BRICS indicates that there is a long-term stable relationship between urbanization and carbon emissions [21]. In addition to these studies on global emissions, some researchers have specifically focused on China. These studies have shown that income—not demographic change—drives China's carbon emissions, besides urbanization and industrial structure significantly affect carbon emissions as well [22]. Furthermore, some scholars examine the impact factors of regional carbon emission in China. They have found that urbanization, GDP per capita, and industrialization can increase carbon emissions, while service level and technology level exert negative effects [23,24].

Extant research on the relationship between transportation and carbon emissions has focused on factors that increase carbon emissions in the transportation sector. However, there has been little work to investigate the effect of transportation infrastructure on carbon emissions. Relative to IDA and SDA, the STIRPAT model can identify a greater number of factors that drive carbon emission, thereby producing more comprehensive conclusions.

To this end, we populate the STIRPAT model with panel data for 283 cities between 2003 and 2013 to study the effects of transportation infrastructure on urban carbon emissions. In doing so, our study makes three key contributions to the literature. First, we explain the effects of transportation infrastructure on urban carbon emissions. Second, whereas most existing studies focus on carbon emissions at the national or provincial level, we evaluate emissions at the city-level. As China is in a critical period of accelerated urbanization. Because China seeks to reduce carbon emissions during this critical period, it is important to study the effects of factors that contribute to urban carbon emissions to help achieve emission reduction targets. Third, we use an improved STIRPAT model to measure the influence of previously unexplored factors on urban carbon emissions.

To address these issues, we have organized this paper as follows. In the following section, we present a mechanism analysis. Then, in Section 3, we describe the model and the variables that comprise it. Section 4 describes the empirical analysis, and Section 5 offers some conclusions and policy implications.

2. Mechanism analysis

We predict that transportation infrastructure affects urban carbon emissions via three mechanisms: population scale, economic growth, and technological innovation (Fig. 1). First, transportation infrastructure can reduce travel costs, enhance regional accessibility, and improve population mobility. As such, it can increase a city's population, which in turn affects urban carbon emissions. According to Fujita et al. [25], when transportation costs are relatively high, manufacturing activities appear substantial, but are actually small. However, when transportation costs decline, population and industrial infrastructure tends to centralize, forming the basis for a city. Fujita and Thisse [26] showed that when transportation costs are sufficiently low, innovative centers tend to formulate. As a result, the social welfare of unskilled workers in the central area tends to be superior to the social welfare of unskilled workers in the peripheral area. Given the free flow of labors, the citizens are expected to concentrate in central areas, resulting in a population scale effect. Moreover, population expansion is likely to affect the city's carbon emissions [27,28].

Second, the construction of transportation infrastructure reduces the geographical distances commuters must travel, as well as the costs of transportation. These effects improve regional accessibility. Development of transportation infrastructure also increases inter-regional trade and contributes to market expansion [29]. These outcomes promote regional economic growth, which