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RESEARCH PAPER

A Quantitative Analysis of Carbon Emissions Reduction Ability of Transportation Structure Optimization in China

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Abstract: In order to develop a low-carbon emissions transportation system, it is important to study the carbon emissions reduction ability of transportation structure optimization. Based on analysis of the impact of transportation structure on carbon emissions, this paper employed a quantitative approach and time series data (1989–2009) to analyze the effect of transportation structure on carbon emissions in China. In this study, a quantitative approach of the decomposition analysis and the impulse response function were combined. Measurements of the quantity change in carbon emissions caused by the transportation structure factor were obtained along with the responses of the carbon emissions to the impulse of the transportation structure optimization. The relationship between transportation structure and carbon emissions was discussed based on empirical results, including: (1) short- and long-term influence of transportation structure on carbon emissions; (2) comparative analysis of transportation structure and other principal factors; (3) the dynamic interaction mechanism between transportation structure and carbon emissions. The outcome of this study proved to be valuable for researchers and decision makers in this field.

Key Words: integrated transportation; carbon emission reduction; decomposition analysis; impulse response function; structure optimization

1 Introduction

As an important infrastructure in the socio-economic system, transportation plays a significant role in society and in people's everyday life. To achieve the carbon emissions reduction target, the transportation supply needs to be cut down. This target may not be attainable due to the growing transportation demand in China which has been caused by its rapid economic development. The optimization of the transportation structure can address the imbalance between the transportation demand and supply, which would be beneficial for sustainable transportation system development in China. Therefore, studies that focus on the development of low-carbon transport in China based on transportation structure optimization are more preferable. We therefore estimated and analyzed the carbon emissions reduction ability of the optimization of the transportation structure in China to provide quantitative information for researchers and people interested in this field. The analysis and recommendation in this study, which are based on statistics, can be beneficial to the development of a low-carbon transportation system and sustainable transportation policy design in China.

Although many researchers agreed that transportation carbon emissions are strongly affected by transportation-mode structure, statistics show that the influence of the transportation structure on carbon emissions varied in different regions and in different periods. Greening[1] compared the effects of the transportation structure on the carbon emission of ten countries of the organization for economic co-operation and development (OECD) in 1970–1993. The maximum was 3.07% (Japan, 1970–1973), and the minimum was –0.3% (Denmark, 1979–1985) in terms of personal transportation; the maximum was 2.55% (Japan, 1979–1985), and the minimum was –1.68% (Japan, 1970–1973) in terms of freight[2]. Therefore, the transportation structure played different roles during different time periods even in the same country. Nevertheless, researchers agree that transportation structure optimization helps in carbon

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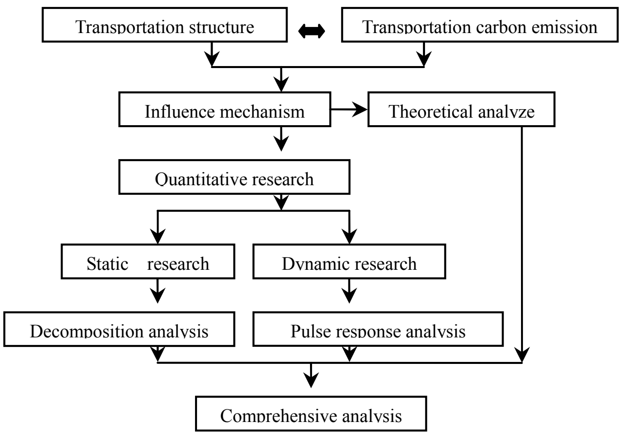

Fig. 1 Research framework

emissions reduction. Mazzarino[3] proved that transportation structure optimization could effectively reduced carbon emissions; a 25% transportation carbon emissions reduction was achieved in Italy in 1995 compared with that in the 1980 level owing to the optimization in the transportation structure.

The carbon emissions created by the transportation sector in China has become a hot issue, but quantitative analysis of the influence of the transportation structure optimization on carbon emissions are rarely found. Existing research on the factors that influence transportation carbon emissions focus on the socio-economic perspective, and the transportation structure factor is neglected. Xu and Du[4] analyzed two influencing factors on the transportation carbon emissions: population and GDP. Population was considered as the most importation factor, and the population group which was between 15 and 64 years old was determined as the biggest contributor of the increase in the transportation carbon emissions. Shen and Chi[5] classified eight factors into three groups (energy intensity, economic level, and population), and regarded economic level and population as the strongest driving factors. Zhang[6] focused on four factors: urbanization, per capita GDP, urban household consumption level, and transportation energy intensity. He suggested that the largest contributor to the increase in urban transportation carbon emissions is the transportation energy intensity in the short term and the urbanization in the long-term.

Existing related articles disagree that the transportation structure influences the energy consumption of the transportation sector and the carbon emissions in China. Timilsina and Shrestha[7] showed that despite the 10,199 kt CO_2 emitted by the transport sector in 2005 compared with that in 1980, a 664 kt reduction in carbon emissions was achieved by the transport structure. Despite that, other researchers insisted that the transportation structure continually contributed to the increase in the transportation energy consumption in China. Zhang *et al.*[8] identified the contribution of the transportation structure to the increase in the energy consumption between 1980 and 2001. The increase in the maximum and minimum energy consumption caused by the transport sector were 7.74 million and 1.54 million tons of standard oil, accounting for 31.92% and 98.09% of the total energy consumption increasing, respectively, during the same period. Zhang[9] attributed the increase in the energy consumption of the urban passenger to the transport structure. Chang *et al.*[10] showed that the carbon emissions caused by the transportation structure in China was approximately 20% of total emission between 2000 and 2005. Since transportation carbon emissions and energy consumption are strongly related, the transportation structure is also a contributor to the increase in carbon emissions.

Based on the above-mentioned studies, there are still many problems which remain unsolved. First, the existing research focuses on the static data analysis (impact measurement based on statistics). The lack of dynamic studies limits the interpretation of the research results. Therefore, the development trend in both the transportation structure and carbon emissions cannot be predicted. Second, related studies show that the transportation structures in different countries and in different periods have different effects on the carbon emissions. Studies that have focused on China are rare and sometimes contradicting, and the research focused on other countries is not applicable to the real condition in China. Third, most related articles in Chinese are qualitative studies, and there are very few quantitative analysis studies. Even the limited studies which exist are inconsistent and lack updated data. Therefore, a quantitative analysis based on long-term and updated data is necessary.

Based on the analysis of the influencing mechanism between the transportation structure and carbon emissions, we combined the decomposition and the pulse response analyses to evaluate the ability to reduce carbon emissions with the optimization of the transportation structure in China in 1989–2009.

2 Methodology

2.1 Research framework

This paper is organized as (Fig. 1): first, this paper theoretically analyzed the influence mechanism between the transportation structure and carbon emissions. Then, static and dynamic analyses were gradually performed. In the static analysis, the decomposition and time-series data analyses were conducted to measure the variation in the transportation carbon emissions in China between 1989 and 2009 caused by the transportation structure factor. The pulse response analysis was used in the dynamic analysis. Based on the construction of a vector auto-regression (VAR) model, pulse response and variance analyses were applied to simulate the responses of the transportation carbon emissions and the transportation