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Decomposition analysis of energy-related carbon emissions from the transportation sector in Beijing

Fengyan Fan, Yalin Lei *

School of Humanities and Economic Management, China University of Geosciences, Beijing 100083, China
Key Laboratory of Carrying Capacity Assessment for Resource and Environment, Ministry of Land and Resource, Beijing 100083, China

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ABSTRACT

In the process of rapid development and urbanization in Beijing, identifying the potential factors of carbon emissions in the transportation sector is an important prerequisite to controlling carbon emissions. Based on the expanded Kaya identity, we built a multivariate generalized Fisher index (GFI) decomposition model to measure the influence of the energy structure, energy intensity, output value of per unit traffic turnover, transportation intensity, economic growth and population size on carbon emissions from 1995 to 2012 in the transportation sector of Beijing. Compared to most methods used in previous studies, the GFI model possesses the advantage of eliminating decomposition residuals, which enables it to display better decomposition characteristics (Ang et al., 2004). The results show: (i) The primary positive drivers of carbon emissions in the transportation sector include the economic growth, energy intensity and population size. The cumulative contribution of economic growth to transportation carbon emissions reaches 334.5%. (ii) The negative drivers are the transportation intensity and energy structure, while the transportation intensity is the main factor that restrains transportation carbon emissions. The energy structure displays a certain inhibition effect, but its inhibition is not obvious. (iii) The contribution rate of the output value of per unit traffic turnover on transportation carbon emissions appears as a flat "M". To suppress the growth of carbon emissions in transportation further, the government of Beijing should take the measures of promoting the development of new energy vehicles, limiting private vehicles' increase and promoting public transportation, evacuating non-core functions of Beijing and continuingly controlling population size.

Introduction

In the 21st century, global warming and the energy crisis pose a serious challenge to sustainable human development. Low carbon development has become the global consensus for growth. However, with the rapid development of the economy and society, cities have become a major source of carbon emissions, and urban transportation is an important contributor to urban carbon emissions. According to UN statistics, urban carbon emissions account for 75% of the total global carbon emissions, in which transportation accounting for 17.5% (Li and Liu, 2014). Our calculation reveals that the transportation

* Corresponding author at: Rm. 505, Administrative Office Building, China University of Geosciences, Beijing 100083, China. Tel.: +86 10 82323525, mobile: +86 13693202513; fax: +86 10 82321006.

E-mail address: leiyalin@cugb.edu.cn (Y. Lei).

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carbon emissions of Beijing in 2012 accounted for approximately 22.28% of the total carbon emissions. In the worldwide, transportation has already become the second highest carbon dioxide (CO_2) emission sector, trailing the electricity and heat generation (IEA, 2014).

Increased transportation carbon emissions have become an important factor restricting the sustainable development of the global economy. Low-carbon transportation and related issues have thus become a substantial topic in the community. Multiple studies have investigated the factors influencing carbon emissions in the transportation sector. Lakshmanan (1997) developed a decomposition scheme to identify the magnitude and the relative effects of the various factors in the U.S. transportation energy use and CO_2 emissions between 1970 and 1991. The results revealed that the growth in the propensity to travel, population, and gross domestic product (GDP) were the three most important factors driving U.S. transportation energy use and CO_2 emissions. Data covering 146 urbanized areas in the United States indicated that the population density, transit share, freeway lane miles per capita, private vehicle occupancy, and average travel time had a statistically significant explanatory effect on passenger travel-related CO_2 emissions (Mishalani et al., 2014). Lu et al. (2007) adopted the Divisia index approach to explore the effects of five factors on the total carbon dioxide emissions from highway vehicles in Germany, Japan, South Korea and Taiwan during 1990–2002. Their results suggested that the rapid growth in the economy and of vehicle ownership were the most important factors for the increased CO_2 emissions, whereas population intensity contributed significantly to decreasing the emissions. Timilsina and Shrestha (2009) analyzed the potential factors influencing the growth of transportation sector CO_2 emissions in selected Asian countries during 1980–2005 and identified changes in per capita GDP, population growth and transportation energy intensity as the main factors driving transportation sector CO_2 emission growth. Schipper et al. (1997) performed a decomposition analysis on the changes in freight energy use of 10 industrialized countries from 1973 to 1992 to identify the relative contribution of the activity, modal structure, and energy intensity to increases in the energy use observed in each country. The major findings were as follows: Domestic freight volumes increased with trucks carrying the majority of the increased freight. Freight energy use and the associated carbon emissions increased markedly and were rising when compared to the emissions associated with passenger travel. The energy used for freight will continue to increase unless substantial reductions occur in the energy intensities of truck freight. Andreoni and Galmarini (2012) also used a decomposition analysis to investigate the main factors influencing CO_2 emissions from the water and aviation transportation sectors in Europe during 2001–2008. The results indicated that economic growth was the main factor behind CO_2 emissions. Kwon (2005) investigated the key factors in the change in CO_2 emissions from car travel in Great Britain over the last 30 years using the IPAT identity. The results revealed that car driving distance per person was a dominant force for the growth of emissions. Technology factors, such as fuel efficiency and substitution of diesel fuel, partly cancelled out the growth effects, while the contribution of the other factors was relatively small. Mazzarino (2000) adopted a comparative static approach to analyze the main factors by determining the variation of transportation sector CO_2 emissions in Italy during 1980–1995. The results indicated that the main driving force in the variation of CO_2 emissions was the growth of the GDP. Timilsina and Shrestha (2009) determined the factors responsible for the growth of transportation sector CO_2 emissions in 20 Latin American and Caribbean (LAC) countries during 1980–2005 by decomposing the emission growth into components associated with changes in the fuel mix, modal shift, economic growth, emission coefficients and transportation energy intensity. The key finding was that economic growth and the changes in transportation energy intensity were the principal factors driving transportation sector CO_2 emissions growth in the countries considered.

Currently, research on the factors influencing transportation carbon emissions in China remains limited. Wang et al. (2011) applied the logarithmic mean Divisia index (LMDI) method to determine the factors that influence changes in transportation sector CO_2 emissions in China over the period 1985–2009. The results showed that highway transportation was the most substantial source of CO_2 emissions. The per capita economic activity effect and transportation modal shifting effect were primarily responsible for driving the growth in the transportation sector CO_2 emissions. The transportation intensity effect and transportation services share effect were the main drivers of the reduction of CO_2 emissions in China. However, the emission coefficient effect played a minor role over the study period. Through a daily activity survey conducted in Beijing from 2000 to 2011, Wang and Liu (2014) examined the effects of individual travel behavior on carbon emissions from urban transportation in Beijing. The results showed that the vehicle-use intensity, disposable income per capita and population size were the main drivers for the increase of household daily travel carbon emissions. Both the transportation intensity and emission coefficient had significant effects on the reduction of carbon emissions. However, the transportation mode share played a minor role. Based on data covering Beijing, Tianjin, Shanghai and Chongqing, Su et al. (2011) empirically analyzed the factors influencing urban transportation carbon emissions during 1995–2009. The results showed that the city population size and vehicle ownership had important effects on urban transportation carbon emissions by influencing passenger and freight turnover. Urban passenger and freight turnover had significant positive effects on urban transportation carbon emissions, whereas the proportion of buses had a significant negative effect. Yang et al. (2014) and Wu et al. (2012) applied the LMDI decomposition method to analyze transportation sector carbon emissions in Jiangsu and Shanghai, respectively, and yielded consistent conclusions: the positive driving factors were the economic output, population size and industrial structure, whereas the negative drivers were the transportation energy structure and energy intensity. Shen and Chi (2012) analyzed the driving factors of CO_2 emissions from transportation sector in China from 1991 to 2009. The results showed that the main positive drivers of CO_2 emissions from the transportation sector were the urbanization level, proportion of tertiary industries and total population, and that the main negative drivers were the traffic turnover per unit of GDP, energy consumption per unit of traffic turnover, secondary and tertiary industries value per unit of population, and the contribution of tertiary industry to GDP. Based on the STIRPAT model and the energy-related carbon emissions from