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Path analysis of factors in energy-related CO_2 emissions from Beijing's transportation sector

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ABSTRACT

The transportation sector is one of the major driving forces of carbon emissions. Identifying the factors that affect CO_2 emissions from the transportation sector is important to build a low-carbon city. Most existing research focuses on the total effect of factors on CO_2 emissions while the indirect influence is also the driving force of CO_2 emissions. Additionally, identifying the causal relationship between variables is helpful to study the mutual acting mechanism. Therefore, this paper uses the path analysis model to estimate the direct, indirect and total influences of driving factors on transportation CO_2 emissions in Beijing and investigate the causality relationships between variables. The results show that reducing energy intensity and transportation intensity are the key factors in controlling the increase of transportation-related CO_2 emissions. Population has the greatest positive impact on CO_2 emissions because an increasing population is leading to growth in energy consumption and the number of motor vehicles. However, population could indirectly affect the energy intensity and transportation intensity to reduce carbon emissions. Moreover, motor vehicles increase CO_2 emissions due to the growth in private car population and its low energy efficiency. And, the change in the economic growth pattern somewhat inhibits the growth rate of CO_2 emissions by reducing the energy intensity and transportation intensity indirectly. To further suppress the growth of transportation carbon emissions, the following steps should be taken: appropriately improve the quality of population, control the scale of motor vehicles, develop and promote clean energy, and reduce traffic energy intensity and transportation intensity.

1. Introduction

A series of problems, such as high carbon emissions, air pollution and climate change, have been caused by rapid growth in energy consumption. With the rapid development of the economy and society, the city has become the main source of energy consumption and carbon emissions. The transportation sector is a critical sector of the national economy and also a significant source of CO_2 emissions (Zhang and Nian, 2013). Transportation is the fastest-growing source of energy consumption in Beijing. According to statistics from the Beijing Statistics Bureau, the proportion of transportation energy consumption of the total will grow to 40% by 2030. The transportation sector has become the largest and fastest-growing oil-

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consuming sector (Sanz et al., 2014; Xu and Lin, 2015b). Energy consumption in the transportation sector increased from 1.38 million tons of standard coal equivalent (tce) in 1990 to 12.04 million tce in 2014. For Beijing, high population density, traffic congestion, traffic energy consumption and many other problems are significant barriers to developing low-carbon transportation. Identifying the key driving forces of CO_2 emissions is essential for low-carbon transportation and emissions reduction policies.

Scholars have conducted extensive research regarding the driving forces governing energy-related CO_2 emissions in the transport sector. Many studies use the decomposition analysis (Lakshmanan and Han, 1997; Zheng et al., 2008; Zhang et al., 2011; Wang et al., 2011; Loo and Li, 2012; Gambhir et al., 2015; Xie et al., 2016; Luo et al., 2016) to investigate the driven forces of carbon emission, and most of them confirm that the main influencing factors are transportation energy intensity (Wang et al., 2011; Zhang and Nian, 2013; Timilsina and Shrestha, 2009), transportation intensity (Wang et al., 2011; Mazzarino, 2000; Wang and Liu, 2014; Andreoni and Galmarini, 2012; Fan and Lei, 2016), economic growth (Xu and Lin, 2015b; Li et al., 2013; Loo and Li, 2012; Wang et al., 2011), per capita vehicle ownership (Mishalani et al., 2014; He and Chen, 2013; Xu and Lin, 2015a), and population (Timilsina and Shrestha, 2009; Kwon, 2005; Wang and Liu, 2014; Wang et al., 2011). However, scholars had to propose many methods to eliminate multicollinearity of multivariate regression analysis when the driving factors exist multicollinearity.

Because the existence of interrelationships among driving factors, it signifies that the indirect influence is also the driving force of the CO_2 emissions. In addition, in order to identify the mutual acting mechanism between the factors and CO_2 emissions, it is very important to study the causal relationship between every two variables. However, existing studies have not probed the unique characteristics of direct and indirect effect of factors on CO_2 emissions from Beijing's transportation sector, and investigated the causal relationship between CO_2 emissions and the variables. Therefore, we choose path analysis model to avoid multicollinearity among variables and reveal all aspects of the relationship among variables. Path analysis was developed as a method of decomposing correlations into different components to interpret effects and lucubrate causality through the related surface phenomena (Wright, 1921, 1934; Finney, 1972).

Path analysis provides two key advantages when compared to decomposition analysis. First, the path analysis provides parameter estimates for direct, indirect, and total effects. This approach contrasts with a typical regression analysis, which estimates only direct effects. Second, path analysis facilitates the assessment of causal linkages. As such, the analysis presented in this paper fulfills three goals by (i) estimating of the latent indirect effect and the direct effect of the driving forces on CO_2 emissions, (ii) revealing the interaction between driving factors and ranking of their influence in CO_2 emissions with respect to their influential intensity, and (iii) enabling of the government to establish a sustainable development strategy and energy conservation policy.

The paper proceeds as follows: The next section discusses the reasons for selecting the path analysis model. The following sections focuses on establishing a path diagram by deleting the non-significant paths, calculating the latent indirect effect and direct effect of the independent variables on CO_2 emissions, and applying a goodness-of-fit test of the model. The penultimate section explores the results of the path analysis. The final section presents some interesting conclusions and policy suggestions.

2. Literature review

2.1. Driving forces cores of transportation CO_2 emissions

The high energy consumption and growing CO_2 emissions from the transportation sector has promoted many scholars to research the main factors causing traffic CO_2 emissions. Motor vehicles have been widely acknowledged as a major contributor to the increase in CO_2 emissions in the transportation sector (Mishalani et al., 2014). Melo and Ramli (2014) observed that car ownership (vehicle stock per capita) was not only positively correlated with total fuel consumption, but also created excessive emissions and energy consumption (Chiou et al., 2009). Xu and Lin (2016) found that rivate vehicles were more important than cargo turnover in emission reduction because of its relatively inefficient and excessive growth. Sun et al. (2013) analyzed China's urban traffic structure and maintained that vehicle numbers, fuel consumption per hundred kilometers and annual mileage were the main factors exerting influence on urban transportation energy consumption. Moreover, Musti and Kockelman (2011) argued that automobile ownership plays a pivotal role in determining vehicle use, vehicle emissions, and fuel consumption.

Scholars have reached different conclusions on the relationship between economic growth and CO2 emissions in the transportation sector. Xu and Lin (2015a) adopted provincial panel data and nonparametric additive regression models to examine the key factors in CO_2 emissions in China's transportation sector. The estimation results showed that the nonlinear effect of economic growth on CO_2 emissions was consistent with the Environmental Kuznets Curve (EKC) hypothesis. Melo and Ramli (2014) observed that average real income levels were positively correlated with total fuel consumption. Zhang et al.(2016) found that China's transport service demands, final energy consumption, and the corresponding carbon emissions would increase rapidly with the substantial economy growth by using TIMES (an acronym for The Integrated MARKAL-EFOM System) model. Li et al. (2013) used the average devise index (ADI) method and found that economic growth was mainly responsible for driving carbon emissions growth. Loo and Li (2012) and Wang et al. (2011) reached the same conclusion by adopting the Kaya identity and the logarithmic mean Divisia index (LMDI) method.