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Railway transportation and environmental efficiency in China

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ABSTRACT

Railway is one of the most efficient and environmental-friendly ways to transport people and goods. High-speed railway has been developing rapidly and the railway mileage has increased by 21.18% in China during the period of 2006–2011 and thus it is interesting to evaluate whether the railway transportation has reduced the environmental impact of transport in China. In this paper, we first use a non-radial DEA under managerial disposability to measure the environmental efficiency of 30 regions in China; then we propose a panel beta regression with fixed effects to model the impact of railway transportation on environmental efficiency. The results indicate that the environmental efficiency slowly increased during 2006–2011 and it exhibits regional disparities with the eastern area having the highest environmental efficiency and the western area being the lowest one; Moreover, we also find a significant positive impact of railway transportation on higher environmental efficiency.

Introduction

Since economic reform in 1978, China has experienced fast economic growth with a 9.5% annual GDP growth rate during 1978–2011, however, this achievement has been accompanied by serious environmental deterioration. In the past three decades, scale-oriented economic development in China has been associated with high-energy consumption and consequently environmental pollution. Faced with the growing environmental constraints and the severe energy security, Chinese government has proposed in its "Twelfth Five-Year Plan" that they would reduce energy consumption per unit of GDP by 16%, CO2 emissions per unit of GDP by 17%, and SO2 per unit of GDP by 8% by 2020. Currently, the goal of achieving reduced use of energy and improving environmental efficiency has become a basic task of all levels of government.

Transportation is a sector that involves resource usage and energy consumption, and is also important for building a resource-saving and environmental-friendly society. With rapid economic and social development in recent years, transportation has become one of the fastest growing industries in China. The further development of Chinese transportation sector is facing a resource and environmental constraint that on the one hand, there is higher demand for transportation volume, and on the other hand preservation of the environment is important.

Railway is one of the most environmentally friendly and efficient ways to transport people and goods. High-speed rail has been developing rapidly in China since 2006. According to *China Statistical Yearbook 2014*, China has the world's largest high-speed rail network in December 2014 with 16,000 km of track in service. The nationwide high-speed railway network, which extends to all provinces and regions in China, consists mainly of conventional track railways and newly-built lines

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with passenger volume of 2,122,992 million and freight volume of 40.99 billion tons. In the meantime, as a carbon emissions-intensive industry, transportation has been constrained from the international community and national government in terms of emissions. Therefore, it is important to explore how railway transportation impacts on environmental efficiency in China.

Thus, the objective of this paper is twofold. First, we firstly use a non-radial DEA under managerial disposability to measure the environmental efficiency of 30 regions in China, which is a more accurate measure combining the environmental management strategies with undesirable outputs. Second, we propose a panel beta regression with fixed effects to model the railway transportation's impact on environmental efficiency, which is better at modeling fractional response than traditional linear regression and Tobit regression. Our empirical finding shows that the railway transportation has significant positive effect on the improvement of environmental efficiency in China.

The remainder of the paper is organized as follows: Section "Literature review" reviews related literatures. The methodologies and model setting are introduced in Section "Methodologies and model setting". Section "Data and environmental efficiency" describes the data and measurement of environmental efficiency. The empirical results of railway transportation's impact on environmental efficiency is presented in Section "Railway transportation's impact on environmental efficiency". Section "Conclusion" concludes.

Literature review

Environmental efficiency is used to measure the actual and potential pollution emissions, implying the distance between an economic (region) pollution emission and its minimum pollution emission under the conditions of equal amounts of factor inputs and outputs (Zhang, 2009). From existing literature, the evaluation of energy and environmental performance is often presented by environmental efficiency indices which can be constructed through mathematics programming methods such as conventional data envelopment analysis (DEA) models (Charnes et al., 1978), non-radial DEA models (Wang et al., 2013), Range-Adjusted Measure based DEA (RAM-DEA) models (Sueyoshi et al., 2010), and directional distance function (DDF) models (Färe and Grosskopf (2010)).

Some scholars have studied China's environmental efficiency using DEA method. Hu and Wang (2006) proposed an environmental efficiency index of total factors and used it to measure energy efficiency of 29 Chinese provinces, municipalities and autonomous regions; Li et al. (2013) made use of a super-SBM model to measure 30 regional energy efficiency and environmental efficiency in China during the period 1991–2010. Given that China is a country with uneven distribution of human capital and unbalanced development of technology, more stringent environmental control regulations may impact economic growth and environmental efficiency.

Besides, most of existing paper did not separate the output into desirable and undesirable output. Traditional DEA method usually indicates that producing more outputs relative to fewer inputs is a criterion of efficiency. In the presence of undesirable (bad) outputs, e.g. air pollutants and hazardous water. Thus, it is important to use technologies to recognize desirable (good) outputs and undesirable (bad) outputs relative to fewer inputs as efficiency.

In this paper, we use Non-radial natural disposability DEA method, combined with the environmental management strategies, which is modified so as to take undesirable outputs into account, to analyze environmental efficiency of different regions in China.

Regression models are commonly used to process data and reflect the correlation between dependent and independent variables, of which the linear regression model is a commonly used one. However, when the dependent variable, such as environmental efficiency, is restricted to the interval (0, 1), the fitted values of the response variables generated by linear regression models may beyond the reasonable range. A possible solution to this problem is transforming the dependent variable to make the response values stay in the given interval, and model the mean of the transformed variable as a linear predictor based on a set of independent variables. But this approach also has some disadvantages. On the one hand, the model parameters will not be easily interpreted in terms of the original response before transformation. On the other hand, the normality assumption can be violated because measures of proportions typically display asymmetry. Ferrari and Cribari-Neto (2004) proposed beta regression to modelproportional response. The beta distribution is very flexible for modeling proportional data because its density can be in different shapes. Guolo and Varin (2014) used beta regression to analyze bounded time series, with application to Canada Google influenza trends. Swearingen et al. (2011) introduce beta regression as a possible method of modeling extremely skewed distributions as evidenced in ischemic stroke lesion volumes. However, to our best knowledge, there is no existing literature to model panel proportional response data. Compared with cross section and time series data, panel data contains more information, and can measure the individual effects that are not recognized in cross section or time series data. In this paper, we propose a panel beta regression with fixed effects to analyze the impact of railway transportation upon environmental efficiency in China.

Methodologies and model setting

Non-radial DEA under managerial disposability

In this paper, we use non-radial methodology under managerial disposability to measure the environmental performance of DMUs proposed by Sueyoshi and Goto (2010, 2012a,b,c). Managerial disposability refers to a situation when DMUs with

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