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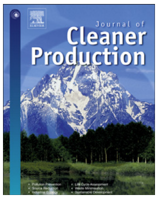

Sustainability performance for China's transportation industry under the environmental regulation

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ABSTRACT

Traffic and transportation industry is a carbon-intensive industry in China. The implementation of environmental regulation is of important practical significance. Nowadays, literatures lack of quantitative analysis on transport industry's sustainability performance under the environmental regulation. By using a directional distance function, this paper aims to investigate the effect of environmental regulation on this industry. Furthermore, this paper measures its green total factor productivity under the general intensity of regulation and strict regulation from 2000 to 2010. Results show that the economic growth mode in transportation industry is still the extensive mode, while there is great potential for the improvement of energy saving and production.

1. Introduction

Transportation industry in our country is an energy intensive industry. In 2010, the total oil consumption of this industry accounted for 38.2% of total demand in whole society, while its carbon dioxide emissions ranked second only after oil processing, coking and nuclear fuel processing industry, accounted for 18.9%. In China, a resource-saving and ecology-friendly society has been gradually constructed by the government (Song et al., 2015a,b). Therefore, environmental regulation policy is of great importance to this industry. Policies can promote energy conservation and emissions reduction. So very naturally the questions arise. How does environmental regulation promote the efficiency of production in transportation industry? What's the condition of environmental regulation policy which makes the most reasonable results? Existing literatures lack of quantitative analysis about this industry's production efficiency under the environmental regulation.

To measure the changes of companies' productivity, there are a lot of different indicators for calculation, but total factor productivity index is one of the most commonly used indices. As for the calculation method, most scholars use DEA model, which is first proposed by Charnes et al. (1978) formally. DEA model has absolute advantages for dealing with multiple outputs and multiple inputs with having no need to assume any particular functional forms relating to input and output (Song and Zheng, 2016). However, the traditional measurement of total factor productivity measure does not embody the idea of maximizing the expected output and minimizing the unexpected output, so it has the certain insufficiency (Yang et al., 2011). In fact, during the real production activities, far from being avoided, the reduction of undesirable output is often accompanied by a reduction in expected output. Based on this point, Chung et al. (1997) tried to improve the traditional DEA model, putting forward a general environmental production technology, which was based on the directional distance function and reflected the weak disposability of the undesirable output. Meanwhile, they also put forward Malmquist-Luenberger productivity index which was based on directional distance function. Fare et al. (1994) made a further extension on Caves et al. (1982)'s method, they made it widely applicable no matter whether the technology index was invalid or not. What's more, they decomposed the Malmquist productivity index into the part of efficiency changes and the part of technological advances. As a revision of the Malmquist productivity index based on directional distance function, it can also be decomposed into two parts, in order to verify whether environmental regulation can promote the technological progress in enterprises. At present, the directional distance function was used for a variety of research. Hu et al. (2008) used the

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directional distance function to estimate the input-output efficiency of 30 provinces and regions in China, and did the sorting of technical efficiency at the provincial level. Wang et al. (2008) used directional distance function and Malmquist Luenberger index method to measure CO2 emissions of the APEC 17 countries and regions from 1980 to 2004, based on the growth of total factor productivity. They also decomposed Malmquist-Luenberger index into efficient change factor and technological progress factor, in order to test whether environmental regulation could promote technological progress. Wang et al. (2011) used directional distance function to construct a calculation model for energy efficiency. They also measured the energy efficiency, using the Chinese provincial panel data. Directional distance function solves the measurement problem in different efficiency when the input-and-output factors are in different directions at the same time, however, it also has its limitations. Zhou et al., (2012) argued that, in the actual production, the influence of the input-and-output to the total factor productivity was not always the same. Meanwhile, traditional directional distance function to the total factor productivity was overvalued. So they propose the non-radial directional distance function model, assuming that different input-and-output factors had different efficiency loss and that the elements were given different weights. Then the paper adds to a growing body of researching using no-radial DEA on energy efficiency (Song et al., 2013a,b, Song et al., 2014; Johnson and Ruggiero, 2014; Wu et al., 2015). In addition, Choi et al. (2012) employed a non-radial slacks-based DEA model for estimating the potential reductions and efficiency of CO2 emissions for China. Wang et al. (2013) analyzes China's regional total-factor energy and environmental efficiency within a joint production framework of considering both desirable and undesirable outputs, as well as energy and non-energy inputs. Bi et al. (2014) employed the slacks-based DEA model to examine whether environmental regulation affects the energy efficiency of China's thermal power generation. They found that decreasing the discharge of major pollutants can improve both energy performance and environmental efficiency. Song et al. (2015a,b) measured the innovation efficiency of an enterprise with a DEA model and then discussed how financing constraints caused by political connections had differential effects on innovation efficiency. Zhang and Wei (2015) examined and decomposed dynamic changes in total factor carbon emissions performance within the transportation sector in China, incorporating the impact of regional heterogeneity. Song and Zhou (2015) used the super-SBM model to calculate the environmental efficiencies of Chinese provinces and cities and analyzes the relationships among trade, the economy, and environmental quality in China. Zhou et al. (2016) proposed a Malmquist energy conservation and emission reduction performance index (MECERPI) to assess the performance changes in energy use and pollutant emissions over time.

Based on previous studies, this paper applies the no-radial directional distance function model to measure and analyze total factor productivity in transportation industry. With the analysis of features of the return to scale in decision making units, we use the model of directional distance function pointing to the direction of the undesirable output vector, and define two different intensity of environmental regulation: one is the general intensity of regulation, the other one is strict regulation. We focus on the transportation industry in provinces and cities all over the country, trying to study different performance of total factor productivity under different intensity of regulation. On the basis of this model, putting forward the revised Malmquist-Luenberger index is also a need for verifying the ‘Porter Hypothesis’ in transportation industry.

The paper is organized as follows. Section2 discussed the methodology, and Section 3 describes the data. Section 4 presents the empirical results, and we give the conclusions and policy recommendations in Section 5.

2. Methodology

2.1. Non-radial directional distance function

First of all, set up production possibility set. In the production process, input factors can bring desirable and undesirable output at the same time. One is $x = (x_1, x_2, x_3, \ldots x_n) \in R_N^+$ which represents input vector, the second one is $y = (y_1, y_2, y_3, \ldots y_n) \in R_M^+$ which indicates the desirable output vector, while the third one is $z = (z_1, z_2, z_3, \ldots z_j) \in R_J^+$ which stands for the undesirable output vector, so production technology set can be defined by the following equation (1):

$$T = \{(x, y, z) : x \ \ can \ \ produce \ \ (y, z)\} \tag{1}$$

Set T which represents Production Technology includes desirable output and undesirable output. Now let's set its Output Set as follows:

$$P(x) = \{(y, z) : (x, y, z) \in T\} \tag{2}$$

Output Set P(x) has three characteristics. They are closed, bounded and convexity respectively. This collection will take both desirable output and undesirable output into consideration. But if so, that's not good enough to make concrete calculation and analysis, so this article introduces the concept of directional distance function to explain. However, traditional algorithm, just as the directional distance function, will overestimate its efficiency, so Zhou et al. (2012) define a radial directional distance function. It's shown in Fig. 1:

Its definition can be shown as below:

$$\overrightarrow{D}\left(x, y, z; -g_x, g_y, -g_z\right) = \sup\left\{w^T\beta : ((x, y, z) + g \times diag(\beta)) \in P\right\} \tag{3}$$

$$g = \left(-g_x, g_y, -g_z\right) \tag{4}$$

Now we assume that there are k decision making units, that is, the number of the region is k, and the input and output vector of the kth region is $(x^{k'}, y^{k'}, z^{k'})$. We also assume that each kind of undesirable output exists in a certain region once at least, and each region has one undesirable output at least, then the directional distance function of the kth region can be solved by the following linear programming:

$$\overrightarrow{D}\left(x^{k'}, y^{k'}, z^{k'}; -g_x, g_y, -g_z\right) = \max w^T \overrightarrow{\beta} \tag{5}$$

$$\sum_{k=1}^{K} \lambda^k x_n^k \le x_n^{k'} - \beta_{xn} g_{xn} \quad n = 1, 2, \ldots, N \tag{6}$$

$$\sum_{k=1}^{K} \lambda^k y_m^k \ge y_m^{k'} + \beta_{ym} g_{ym} \quad m = 1, 2, \ldots, M \tag{7}$$

$$\sum_{k=1}^{K} \lambda^k z_j^k = z_j^{k'} - \beta_{zj} g_{zj} \quad j = 1, 2, \ldots, J \tag{8}$$

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