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Evaluating the impact of transport investment on the efficiency of regional integrated transport systems in China

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ABSTRACT

The development of transport infrastructure is characterized by intensive capital input, intensive energy consumption, and pollution emissions. Against the background of the continuous intensification of resource and energy constraints in China. Therefore, the analysis of China's regional transport efficiency and its determinants has practical significance. This paper attempts to evaluate regional total factor transport efficiency in China based on the Super-SBM DEA model considering undesirable output and explores the influence factors of transport efficiency in China during the period 1995–2012. The empirical results indicate that during the research period, most provinces in China are not performing efficiently in transport systems. Additionally, the overall average level of China's total factor transport efficiency is low and the spatial pattern of the total factor transport efficiency demonstrates a declining trend from eastern to western China, which coincides with the spatial pattern of economic development in China. The analysis of the influence factors by the regression model shows that economic development and government influence can decrease overall transport efficiency, while industrial structure, population density, and geographical position can influence transport efficiency. The influence of these factors varies by region. Finally, this paper provides policy recommendations to improve transport efficiency in China.

1. Introduction

An efficient and reliable transport system is the backbone of the development of any national or regional economy. Since the beginning of its economic reforms and an open-door policy in 1978, and especially since the fiscal decentralization in the 1990s, investment in transportation infrastructure in China has improved substantially, with both the central and local governments actively involved in the development of transport infrastructure. As Fig. 1 presented below shows, government investment in fixed transport infrastructure increased from 24.85 billion RMB[1] in 1978 to 14,464.21 billion RMB in 2011, especially in roads. In parallel with these investment improvements, there has been a remarkable expansion of transport infrastructure in China, as indicated in Table 1 below. The total length of railway and expressways, for example, increased rapidly from 51,700 km in 1978 and 500 km in 1990 to 103,100 km and 104,400 km in 2013, respectively. By 2013, China had the largest high-speed rail (HSR) network in the world (9760 km), accounting for 46% of the world total (Jiao et al., 2014; UIC, 2013). In addition, there are also many aggressive transport development plans under construction.

The development of transport infrastructure is characterized by intensive capital input, intensive energy consumption, and pollution emissions. For instance, according to the International Energy Agency (IEA), the transport sector accounts for about 22% of the global CO_2 emissions, which is the second-largest sector (IEA, 2010). In China, the transport sector contributed about 7% of the national CO_2 emissions (IEA, 2010). Therefore, attempting to reduce resource consumption under the premise of ensuring output is a central theme in the development of sustainable transport worldwide. Since the end of 20th century, and especially in recent years, many of the problems of the development of transport infrastructure in China have worsened, including overexpansion, duplicated construction, and unreasonable competition, among others (LU, 2012). These problems are primarily the result of the ignorance of national conditions, stage of development, and tendency during transport planning. Against the background of the continuous intensification of resource and energy constraints in China, how to improve transport efficiency while maintaining

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[1] The RMB is the official currency of the People's Republic of China, and is the abbreviation of renminbi.

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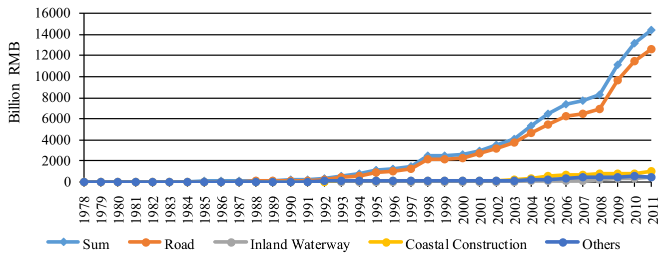

Fig. 1. Investment trends in transport infrastructure in China (1978–2011). *Note:* (1) Source: China Transport Statistical Yearbook, 2012. (2) Investment figures are calculated in constant 2011 prices.

Table 1
Total length of transport lines in China (10,000 km).*Source:* Yearbook of China Transportation and Communications, 2012; China Statistical Yearbook, 2014.

Year	Railway	Highway	Expressway	Inland waterway	Civilian flight routes	Pipeline
1978	5.17	89.02	0	13.6	14.89	0.83
1980	5.33	88.33	0	10.85	19.53	0.87
1990	5.78	102.83	0.05	10.92	50.68	1.59
2000	6.87	140.27	1.63	11.93	150.29	2.47
2005	7.54	193.05	4.1	12.33	199.85	4.4
2010	9.12	400.82	7.41	12.42	276.51	7.85
2013	10.31	435.62	10.44	12.59	410.6	9.85
2013/1978	1.99	4.89	208.8	0.93	27.58	11.87

socio-economic development is especially important for China. However, globalization has brought China closer than ever to the rest of the world, not only through its trade and transport networks, but also through the many transport-related issues that seem to be common among countries (Ng and Wang, 2012). Therefore, our analysis on transport efficiency in China is meaningful and contributes to the literature focused on sustainable transport development. Furthermore, China is diverse in terms of geographical conditions, socio-economic levels, and development policies. From one region to another, there are significant differences in transport efficiency. Hence, it is necessary to examine transport efficiency in China on the regional level.

Therefore, understanding transport efficiency and its influencing factors for each province in China is of particular importance because transport systems are a critical element of China's path towards rapid economic growth, urbanization, and sustainable development. The main objective of this paper is to analyze the total factor efficiency of regional integrated transport systems by province and to explore the determinants that affect transport efficiency. To this end, we apply the super slacks-based data envelopment analysis (Super-SBM DEA) with the undesirable outputs framework proposed by Tone (2001, 2002, 2003). More specifically, we estimate the regional total factor transport efficiency (TFTE), incorporating the CO_2 emissions from China's regional integrated transport systems, from 1995–2012. The Super-SBM DEA model was originally proposed by Tone (2001, 2002, 2003) and then extended by Zhou et al. (2006), Chang et al. (2013), and Li et al. (2013) by adding the undesirable output into both the objective and the constraint functions. The key advantages of applying the Super-SBM DEA to examine transport efficiency are that (1) the modeling framework can directly treat the undesirable output as output following the actual production process and (2) it allows the user to distinguish various decision making units (DMUs), achieving 100% data envelopment analysis (DEA) efficiency.

The remainder of this paper is structured as follows: the next section presents a brief review of the literature on transport efficiency assessments. This is followed by discussions on data collection and the methodology used in our regional transport efficiency analysis framework. The Section 4 presents an analysis of changes in transport efficiency that have resulted from transport developments and the Section 5 provides the empirical analysis of the influence factors of regional transport efficiency using the regression model. Finally, in the conclusion, we present an overview of our key findings as well as provide policy implications.

2. Transportation efficiency assessments: a literature review

The term *efficiency* refers to the relationship between the real or observed values of output(s) and input(s) and the optimal values of the input(s) and output(s) used in a production process (Karlaftis and Tsamboulas, 2012). As an important means of promoting the operational efficacy and service quality of transport systems, efficiency analysis is one of the most widely investigated areas within transport research. In this section, we discuss the measurement models used in evaluations of transport efficiency, and then examine the research using DEA to study transport efficiency in China.

Generally, three empirical methods are used to quantify the performance of DMUs: ratio indicators, production function models, and non-parametric models. Most early research used ratio indicators, such as vehicle hours per employee or vehicle kilometers per active vehicle, to evaluate transport efficiency (Fielding, 1992; Lee, 1989; Mackie and Nash, 1982; Markovits-Somogyi, 2012; Oum et al., 2008). The difficulty with ratio indicators is that they consider only a subset of inputs used by a DMU and, occasionally, only a subset of outputs (Yu et al., 2013). However, this is not the case when multiple inputs and/or outputs are involved (Hensher, 1992). Another way to estimate efficiency is through the application of production (cost) functions, such as the linear function or the Cobb-Douglas function. Production function applications have been used in transport efficiency studies for evaluations of airports (Oum et al., 2008), the maritime (Cullinane et al., 2006), and the railway industry (Coelli and Perelman, 1999). The principle drawback of this type of application is that the construction of a production function form requires prior assumptions about the relationship between the inputs used and the outputs generated. In contrast, non-parametric models do not require a specification of either the production function form or the weights of the different inputs and outputs (Hu and Wang, 2006). Among the various non-parametric methods discussed in the empirical literature, DEA is the primary method used to evaluate transport efficiency within the transport study area. DEA is a method to determine the relative performance of a set of organizational units when there are multiple incommensurate inputs and outputs (Dyson et al., 2001). DEA is based on the original work of (Charnes et al., 1978; Farrell, 1957). Oum and Yu (1994) measured the productive efficiency of railway systems in 19 OECD countries and found that railway systems with greater dependencies on public subsidies are significantly less efficient than similar railways with fewer dependencies on subsidies. Cantos et al. (1999) examined the evolution of productivity in European railways during the period 1970–1995 and found that countries like Sweden, Switzerland, Finland, and Holland achieved efficient behavior throughout the period. With respect to urban transport, Viton (1998) examined the technical efficiency of multi-mode bus transit in the United States and discussed the technological challenges facing the industry. Barnum et al. (2011) proposed a DEA-based procedure to estimate the overall and technical efficiency of the Maryland transit authority.

With the increasing focus on the problems of resource constraints and global climate change, there is a growing body of literature on the