Analysis on the New Green Total Factor Productivity of Transportation Industry

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Abstract: Combined with the new requirements of high-quality economic development for the transportation industry, this paper improves the total factor productivity (TFP) index system from the perspective of economic, social and environmental factors. This paper selects panel data of 30 provinces and cities in China from 2007 to 2018, uses the Super-efficiency Slack Based Model and GML index to make a comprehensive evaluation and analysis on the change of TFP in China's transportation industry. The empirical results show that the new green TFP can more objectively reflect the economic growth and technological progress of the transportation industry after the environmental factors and social costs are included in the evaluation system. During the sample study period, the TFP of the transportation industry shows a trend of first decreasing and then significantly increasing. Moreover, the empirical results vary significantly among provinces and regions, and the TFP value of the eastern region is obviously better than that of the central and western regions. Finally, this paper gives policy suggestions on how to promote the high-quality development of transportation industry in different regions.

1. Introduction

The transportation industry is the foundation and the forerunner industry of the national economy, our country has put forward the new request to the development of the transportation industry. The 19th session of national congress of the communist party of China pointed out that China should promote the high-quality development of transportation and build a safe, convenient, efficient, green and economical modern comprehensive transportation system. In recent years, with the increasing constraints of land, capital, labor, energy, environment and other factors, the development mode of the transportation industry has shifted from the extensive input growth relying on factors to the growth of total factor productivity (TFP). The improvement of TFP of the transportation industry based on the perspective of high-quality development has been put on the agenda. [1]

In 1942, Dutch economist Tinbergen put forward the concept of TFP for the first time, and discussed the effects of other related factors such as technical level on economic growth. [2] In recent years, domestic and foreign scholars have gradually taken energy and carbon emission constraints into consideration when carrying out researches on TFP, and applied them to many fields such as transportation industry. [3] Under the requirements of high-quality economic development in the new era, we should not only consider the economic and environmental efficiency when measuring the TFP of the transportation industry, but should combine with the specific requirements of high-quality development of the transportation industry, and incorporate the restriction of social influence into the evaluation framework. Ou et al.(2013) put forward the three-dimensional comprehensive
transportation theory that efficient and integrated modern comprehensive transportation system should produce fewer road congestion and traffic accidents. Therefore, this paper optimizes the original calculation method of the green TFP, and measures the production efficiency of the transportation industry under the constraints of economic, social and environmental factors in a more comprehensive way, so as to provide reference for the transformation and upgrading of China’s transportation industry.

2. Research methods and index selection

2.1. Model construction

At present, there are many research methods about production efficiency in transportation industry. Since data envelopment analysis (DEA) does not need to set the function form, can obtain the specific productivity value of a single evaluated subject and further decompose the productivity, most scholars choose to use this method to study the production efficiency. This paper uses the Super-efficiency Slack Based Model (a super-efficiency DEA model) and the Global Malmquist-Luenberger (GML) index to study panel data of 30 provinces and cities in China from 2007 to 2018. Due to the epidemic, the release of relevant data in 2018 was delayed, so the TFP value of this paper in 2018 is a forecast value.

2.1.1. Super-efficiency Slack Based Model

Assuming that there are N decision making units and province is taken as the decision making unit in this paper, N=30. Each DMU contains M kinds of inputs, S kinds of expected outputs and Q kinds of unexpected outputs. In this paper, M=3, S=Q=2. The model is specifically constructed as follows:

\[
\begin{align*}
\min \varphi &= 1 + \frac{1}{M} \sum_{m=1}^{M} X_m' \overline{X}_{nk} + \frac{1}{N+Q} \left( \sum_{s=1}^{S} Y_{s} \overline{Y}_{sk} + \sum_{q=1}^{Q} Z_{q} \right) \\
\sum_{i=1,n}^{N} X_{mi} \mu_i - X_{mk}^i &\leq X_{nk}^i \quad m=1, \ldots, M \\
\sum_{i=1,n}^{N} Y_{si} \gamma_i + Y_{sk} &\geq Y_{sk} \quad s=1, \ldots, S \\
\sum_{i=1,n}^{N} Z_{qi} \beta_i - Z_{qk}^i &\leq Z_{qk}^i \quad q=1, \ldots, Q \\
\mu_i &\geq 0 \quad i=1, \ldots, N \\
X_m' &\geq 0 \quad Y_s' \geq 0 \quad Z_q' \geq 0
\end{align*}
\]

Where, \( \varphi \) is the target efficiency; \( X, Y \) and \( Z \) are input factors, expected output factors and unexpected output factors respectively; \( X_{mk}, Y_{sk}, Z_{qk} \) are the relaxation variables of the three factors respectively; \( \mu \) is the weight.

2.1.2. Global Malmquist-Luenberger index

GML index is adopted in this paper to analyze the dynamic change and decomposition of TFP of the transportation industry in all provinces of China. The general calculation formula of GML index is:

\[
GML_{t+1} = \frac{1+B^G(x_t^e, y_t^e, b_t^e)}{1+B^G(x_t^e+1, y_t^e+1, b_t^e+1)}
\]

Where, \( x_t, y_t \) and \( b_t \) respectively represent the input, expected output and unexpected output in the period; \( D^G(x_t^e, y_t^e, b_t^e) \) is the global directional distance function. If GML index is greater than 1, it means that the efficiency value of the transportation industry is increasing in the current year; if it is equal to 1, it means that it remains unchanged; if it is less than 1, it means that the efficiency value
decreases. In addition, GML index can be further decomposed into GMLEC index for measuring technological efficiency changes and GMLTC index for measuring technological progress changes:

\[ GML_t^{t+1} = GECC_t^{t+1} \times GTCC_t^{t+1} \]  

\[ GMLEC_t^{t+1} = \frac{1 + D(x^t, y^t, b_t)}{1 + D(x^{t+1}, y^{t+1}, b_{t+1})} \]  

\[ GMLTC_t^{t+1} = \frac{1 + D(x^t, y^t, b_t)}{1 + D(x^{t+1}, y^{t+1}, b_{t+1})} \times \frac{1 + D(x^{t+1}, y^{t+1}, b_{t+1})}{1 + D(x^{t+1}, y^{t+1}, b_{t+1})} \]  

The technical efficiency index \( GMLEC_t^{t+1} \) measures the degree to which the TFP of the transportation industry in each province moves towards the optimal production frontier; the technological progress index \( GMLTC_t^{t+1} \) measures the distance between the production frontier and the global frontier in the two periods before and after, which reflects the shift of the production possibility boundary caused by technological progress.

2.2. Index selection and data processing
Due to the lack of some data in Tibet, this paper selected the relevant data of 30 provinces (municipalities and autonomous regions, except Tibet) in mainland China from 2007 to 2018. The following indexes were selected:

| Index Type      | Index Name                                      |
|-----------------|------------------------------------------------|
| Input           | Fixed Asset Investment                          |
|                 | Number of Employees                              |
|                 | Transportation Energy Consumption                |
| Expected Output | The Added Value of GDP of Transportation Industry|
|                 | The Density of Road Network                      |
| Unexpected Output | CO₂ Emissions from Transportation               |
|                 | Direct Property Losses in Traffic Accidents     |

The total amount of 8 energy sources, namely raw coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil and natural gas, which are mainly used in the transportation industry are selected for energy input. The calculation method of carbon emissions from energy consumption provided in IPCC Guidelines for National Greenhouse Gas Inventory 2006 is used to calculate CO₂ emissions from transportation industry.[7]

3. Analysis of measurement results

3.1. Static result analysis of Super-efficiency Slack Based Model
As can be seen from Table 2 and Figure 1, the national average of TFP of the transportation industry from 2007 to 2018 is less than 1, which is non-DEA effective and the overall level is low, indicating that the transportation industry has not gotten rid of the extensive development model. At the same time, the change of efficiency value can be divided into two stages. From 2007 to 2011, the efficiency value decreases, while from 2011 to 2018, the efficiency value increases steadily. This means that China's transportation industry has been gradually developing and transforming since the period of the 12th Five-Year Plan, and has achieved good results. TFP is unevenly distributed among provinces and most provinces have inefficient transportation. Shanghai, Ningxia and Qinghai are at the best level in China, constituting the frontier of China's transportation efficiency. But Heilongjiang, Sichuan, Yunnan, Xinjiang and other places have low TFP.

In addition, the regional comparison results show that from 2007 to 2018, the average energy efficiency of the eastern region is higher than the national average, while that of the central, western and northeastern regions is opposite. Combined with the analysis of the provinces, it can be concluded that the provinces with high TFP are mostly located in the eastern region, while the provinces with low TFP are mostly located in the central and northeast regions.
Table 2 TFP of transportation in 30 provinces and cities in China

| Province     | 2007 | 2009 | 2011 | 2013 | 2015 | 2017 | 2018 | Mean |
|--------------|------|------|------|------|------|------|------|------|
| Beijing      | 0.70 | 0.59 | 0.80 | 0.69 | 1.02 | 0.58 | 0.84 | 0.72 |
| Tianjin      | 1.07 | 1.08 | 1.17 | 1.20 | 1.19 | 1.30 | 1.28 | 1.18 |
| Hebei        | 1.08 | 1.13 | 1.12 | 1.13 | 1.13 | 1.11 | 1.11 | 1.11 |
| Shanxi       | 1.06 | 0.42 | 0.30 | 0.45 | 0.48 | 0.48 | 0.45 | 0.67 |
| NeiMongol    | 1.04 | 1.06 | 0.15 | 1.07 | 0.25 | 1.01 | 1.02 | 0.83 |
| Liaoning     | 0.42 | 0.41 | 0.40 | 0.44 | 1.03 | 1.07 | 1.08 | 0.63 |
| Jilin        | 0.53 | 0.43 | 0.36 | 0.40 | 0.36 | 0.33 | 0.31 | 0.39 |
| Heilongjiang | 0.46 | 0.33 | 0.23 | 0.26 | 0.22 | 0.21 | 0.18 | 0.28 |
| Shanghai     | 1.34 | 1.30 | 1.39 | 1.53 | 2.07 | 3.83 | 3.41 | 2.08 |
| Jiangsu      | 1.04 | 1.04 | 1.04 | 1.06 | 1.03 | 1.02 | 1.02 | 1.04 |
| Zhejiang     | 0.66 | 0.60 | 0.50 | 0.54 | 0.50 | 0.55 | 0.54 | 0.56 |
| Anhui        | 0.93 | 0.82 | 0.57 | 0.45 | 0.40 | 0.34 | 0.19 | 0.56 |
| Fujian       | 1.06 | 0.63 | 0.48 | 0.53 | 0.66 | 1.07 | 1.28 | 0.78 |
| Jiangxi      | 0.76 | 0.66 | 0.53 | 0.76 | 0.48 | 0.48 | 0.38 | 0.61 |
| Shandong     | 1.07 | 1.04 | 1.03 | 0.61 | 1.00 | 1.02 | 0.92 | 0.98 |
| Henan        | 1.07 | 1.05 | 0.52 | 0.73 | 0.58 | 0.58 | 0.54 | 0.72 |
| Hubei        | 0.45 | 0.43 | 0.36 | 0.39 | 0.37 | 0.30 | 0.31 | 0.38 |
| Hunan        | 0.64 | 0.50 | 0.43 | 0.53 | 0.47 | 0.46 | 0.45 | 0.51 |
| Guangdong    | 1.02 | 0.54 | 0.48 | 1.01 | 1.03 | 1.03 | 1.08 | 0.83 |
| Guangxi      | 0.35 | 0.32 | 0.32 | 0.40 | 0.37 | 0.44 | 0.45 | 0.37 |
| Hainan       | 1.09 | 1.13 | 1.26 | 1.03 | 0.78 | 1.01 | 0.76 | 0.98 |
| Chongqing    | 1.09 | 1.10 | 0.55 | 0.59 | 0.55 | 0.61 | 0.42 | 0.70 |
| Sichuan      | 0.41 | 0.25 | 0.22 | 0.24 | 0.27 | 0.26 | 0.25 | 0.27 |
| Guizhou      | 1.03 | 1.04 | 0.70 | 1.04 | 1.10 | 1.00 | 1.05 | 1.00 |
| Yunnan       | 0.30 | 0.21 | 0.15 | 0.18 | 0.17 | 0.15 | 0.15 | 0.19 |
| Shanxi       | 0.43 | 0.37 | 0.29 | 0.36 | 0.33 | 0.32 | 0.32 | 0.35 |
| Gansu        | 1.01 | 0.54 | 0.37 | 0.30 | 0.28 | 1.01 | 0.98 | 0.55 |
| Qinghai      | 3.10 | 1.40 | 1.49 | 1.32 | 1.30 | 0.30 | 0.32 | 1.49 |
| Ningxia      | 1.44 | 1.61 | 1.53 | 1.77 | 1.63 | 1.94 | 1.89 | 1.68 |
| Xinjiang     | 0.25 | 0.20 | 0.14 | 0.13 | 0.12 | 0.13 | 0.12 | 0.16 |
| East         | 1.01 | 0.91 | 0.93 | 0.93 | 1.04 | 1.25 | 1.23 | 1.03 |
| Midland      | 0.82 | 0.64 | 0.47 | 0.55 | 0.46 | 0.55 | 0.51 | 0.58 |
| Northeast    | 0.47 | 0.39 | 0.33 | 0.37 | 0.54 | 0.53 | 0.53 | 0.43 |
| West         | 0.95 | 0.74 | 0.54 | 0.67 | 0.58 | 0.65 | 0.63 | 0.69 |
| Mean         | 0.90 | 0.74 | 0.63 | 0.70 | 0.70 | 0.82 | 0.79 | 0.75 |

Figure 1 Average TFP of transportation in 30 provinces and cities in China

3.2. Dynamic result analysis of GML index

GML, GMLEC and GMLTC indexes show a characteristic of volatility during the study period. From the perspective of the driving force of TFP of the transportation industry, the mean value of GMLEC
The index is mostly less than 1, indicating that the technical efficiency of the transportation industry did not significantly improve during the study period. The GMLTC index is greater than 1, indicating that technological progress in the transportation industry plays a leading role in promoting the growth of TFP.

Among the 13 provinces with GML index greater than 1, the GMLTC index of most provinces was significantly greater than the GMLEC index, while among the 17 provinces and cities with GML index less than 1, the GMLEC index of most provinces is smaller than GMLTC index. There is a significant difference in TFP between regions. The average value of eastern and northeastern China is increasing, while that of central and western China is decreasing. The growth of TFP in the northeast region is mainly dependent on technological progress, while the decline of TFP in the central region is the result of the deterioration of technological efficiency. In contrast, the current decline in TFP of the transportation industry in the central and western regions is serious, and there is still much room for improvement in technical efficiency.

### Table 3 GML index and decomposition index of each province and regions

| Province  | GML  | GMLEC | GMLTC | Province  | GML  | GMLEC | GMLTC |
|-----------|------|-------|-------|-----------|------|-------|-------|
| Beijing   | 1.02 | 0.98  | 1.03  | Guangdong | 1.09 | 1.00  | 1.09  |
| Tianjin   | 1.06 | 1.02  | 1.03  | Guangxi   | 1.03 | 1.02  | 1.00  |
| Hebei     | 1.04 | 1.00  | 1.03  | Hainan    | 0.96 | 0.99  | 0.97  |
| Shanxi    | 1.00 | 1.01  | 0.99  | Chongqing | 0.98 | 0.94  | 1.04  |
| Nei Mongol| 1.07 | 1.00  | 1.08  | Sichuan   | 1.00 | 0.95  | 1.05  |
| Liaoning  | 1.14 | 1.10  | 1.03  | Guizhou   | 0.97 | 1.00  | 0.97  |
| Jilin     | 0.97 | 0.95  | 1.02  | Yunnan    | 0.95 | 0.94  | 1.01  |
| Heilongjiang| 0.96 | 0.92  | 1.04  | Shanxi    | 1.00 | 0.97  | 1.03  |
| Shanghai  | 1.07 | 1.11  | 0.96  | Gansu     | 0.94 | 1.00  | 0.94  |
| Jiangsu   | 1.05 | 1.00  | 1.05  | Qinghai   | 0.85 | 0.79  | 1.08  |
| Zhejiang  | 1.02 | 0.98  | 1.04  | Ningxia   | 0.96 | 1.03  | 0.94  |
| Anhui     | 0.94 | 0.91  | 1.04  | Xinjiang  | 0.93 | 0.94  | 0.99  |
| Fujian    | 1.06 | 1.00  | 1.06  | East      | 1.04 | 1.01  | 1.03  |
| Jiangxi   | 0.99 | 0.96  | 1.03  | Midland   | 0.98 | 0.96  | 1.03  |
| Shandong  | 1.03 | 1.00  | 1.04  | Northeast | 1.02 | 0.99  | 1.03  |
| Henan     | 0.99 | 0.94  | 1.05  | West      | 0.97 | 0.96  | 1.01  |
| Hubei     | 0.99 | 0.96  | 1.03  | Mean      | 1.00 | 0.98  | 1.02  |
| Hunan     | 0.99 | 0.97  | 1.03  |           |      |       |       |

### 4. Conclusions and policy recommendations

In general, the TFP of the transportation industry measured by the new accounting method has decreased in general. The reason is that the influence of technological innovation on TFP improvement in recent years is still limited. There are significant differences in TFP among different provinces and
cities, especially in the central and western regions, the productivity of transportation industry is much lower than that of the eastern coastal areas. The eastern region has unique geographical advantages and leads the national level of economic development, and at the same time, it has further widened the gap with the central and western regions in science and technology, talent reserve and other aspects. In the field of transportation, the advantages of eastern coastal areas are also obvious.

In order to promote the high-quality development of transportation, the government should proceed from the following aspects: (1) Change the previous accounting methods of TFP, not only resource consumption and environmental costs need to be considered, but also social cost factors should be included in the accounting system. (2) All provinces and cities should always adhere to the strategic height of high-quality development of transportation, advocate technological economy and green economy, and formulate transportation regulation policies suitable for the region in combination with their own development level. (3) Pay attention to the synchronous development among regions. For the eastern region, the government should continue to increase support for green technology innovation and give play to the driving role of an efficient and integrated transport system in high-quality economic development. For the central and western regions, the government needs to reasonably guide the flow of various factor resources of transportation enterprises, learn from the successful experience of the eastern regions, accelerate the upgrading of transportation technology and the improvement of technical efficiency in a targeted way, so as to realize the coordinated development among regions.

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