Study on Evaluation and Regional Differences of High-quality Economic Development in China ——Based on Green Total Factor Productivity

Jinping Zhang *, Wenxiao Xue
* Corresponding author e-mail: nemo080@126.com, e-mail: XueWX_@outlook.com

School of Economics, Harbin University of Commerce, Harbin, Heilongjiang, China

Abstract—Improving total factor productivity and promoting the green transformation of the economy are important goals for China to move toward the stage of high-quality economic development. The DEA-ML method is applied to estimate the green total factor productivity of Chinese provinces and evaluate the level of China's regional economic quality development. The study finds that, first, China's green total factor productivity has risen slightly over the decade. Especially after the Chinese government emphasized the transition to high-quality economic development in 2017. Second, by region, the eastern region has the highest level of development, while the western region is lagging behind. Third, the improvement of total factor productivity in China mainly benefits from technological progress and is limited by technical efficiency changes. Based on the above findings, the authors make policy recommendations to improve the quality of China's economic development.

Keywords- high-quality economic development; green total factor productivity; Malmquist-Luenberger

1. Introduction

Since the adoption of reform and opening-up policy, China's economy has grown rapidly and made extraordinary achievements. Along with long-term economic growth at the cost of the environment, China is facing problems such as environmental pollution, wasted resources and sluggish economic growth. In addition, the disappearing demographic dividend and the aging population have made it urgent to transform China's economic growth into high-quality development [1]. High-quality economic development refers to a sustainable development approach that is more efficient, environmentally friendly, and equitably distributed. Constructing evaluation indexes in line with the connotation of high-quality economic development, so as to reasonably and effectively evaluate the level of China's regional economy, can correctly understand the current situation of high-quality development of China's regional economy, is conducive to the accumulation of advanced experience in regional economic construction [2], and is of great significance to the high-quality development of China's economy.

At present, scholars generally adopt two methods to measure the level of high-quality economic development: one is to use the entropy weight method to establish a multidimensional index system to evaluate and analyze the level of high-quality economic development [3]; the other way is to use green total factor productivity (abbreviated as green-TFP), which introduces

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environmental factors and non-desired outputs factors, to evaluate the quality of economic development [4]. Based on existing studies, this paper adopts the DEA Malmquist-Luenberger index model approach proposed by Chung et al. to measure the level of quality development of China's regional economy [5]. Unlike the traditional DEA method that focuses only on output and input to calculate total factor productivity, the DEA-ML method introduces undesired output, and only when output increases while undesired output is minimized can production be considered efficient. This paper compiles the data of 30 Chinese provinces from 2010 to 2020, and measures the green total factor productivity as non-desired output to obtain the green total factor productivity extremely decomposition index. The innovation of this paper is to adopt the green total factor productivity to measure the level of high-quality economic development of China's regional economy from both the time dimension and the geographical dimension from the Chinese provinces, which fills the research gap of the existing literature.

2. Materials and Methods

This paper draws on the Malmquist-Luenberger productivity index model, which considers non-desired output, to construct an evaluation system for China's high-quality economic development.

2.1 DEA-ML Model Introduction

The green total factor production index (ML) considering environmental factors is shown in equation (1), and the ML index can be further decomposed into the green technical efficiency index (MLEC) and the green technical progress index (MLTC) shown in equation (2) (3).

$$\boldsymbol{ML^{t,t+1}} = \left[\frac{1+\vec{D}_0^{t}(x_t,y_t,b_t;y_t,-b_t)}{1+\vec{D}_0^{t}(x_{t+1},y_{t+1},b_{t+1};y_{t+1},-b_{t+1})} \times \frac{1+\vec{D}_0^{t+1}(x_t,y_t,b_t;y_t,-b_t)}{1+\vec{D}_0^{t+1}(x_{t+1},y_{t+1},b_{t+1};y_{t+q},-b_{t+1})}\right]^{1/2} \quad (1)$$

$$\boldsymbol{MLEC^{t,t+1}} = \left[\frac{1+\vec{D}_0^{t}(x_t,y_t,b_t;y_t,-b_t)}{1+\vec{D}_0^{t+1}(x_{t+1},y_{t+1},b_{t+1};y_{t+1},-b_{t+1})}\right] \quad (2)$$

$$\boldsymbol{MLTC^{t,t+1}} = \left[\frac{1+\vec{D}_0^{t+1}(x_t,y_t,b_t;y_t,-b_t)}{1+\vec{D}_0^{t}(x_t,y_t,b_t;y_t,-b_t)} \times \frac{1+\vec{D}_0^{t+1}(x_{t+1},y_{t+1},b_{t+1};y_{t+1},-b_{t+1})}{1+\vec{D}_0^{t}(x_{t+1},y_{t+1},b_{t+1};y_{t+q},-b_{t+1})}\right]^{1/2} \quad (3)$$

x_t indicates the input in period t, y_t indicates the desired output in period t, and b_t represents the non-desired output in period t. $ML^{t,t+1}$indicates the green-TFP index considering the non-desired output from period t to t+1. When the measured result $ML^{t,t+1}$>1, it indicates that the analyzed object has experienced green-TFP growth, and when $ML^{t,t+1}$<1, it indicates that green-TFP has deteriorated in that period; $MLEC^{t,t+1}$ reflects the change of efficiency, when this index is greater than 1, it indicates the improvement of efficiency, and vice versa, there is an efficiency decreases; $MLTC^{t,t+1}$ reflects the change of technology, when this index is greater than 1, there is technological progress, and vice versa, there is technological regression.

2.2 Indicator Selection for the Evaluation of High-quality Economic Development

According to the concept and setting of ML, the ML measurement system mainly includes three types of indicators: input, output and non-desired output. (1) The input indicators of the traditional Malmquist index mainly include labor input and capital input, in order to better measure the impact of economic development on the environment, energy input is used instead of capital input; (2) output indicators are indicators to measure the results of regional economic development. (3) Non-desired output indicators are to measure the degree of impact of economic development on ecological environment. It is in the economic production, in addition to the expected output increase, but also to reduce the non-desired output to a certain extent, which is an important element of high-quality economic development. The specific index system is constructed as Table 1.

Table 1 Green Total Factor Productivity Index System

Indicators Name	***Specific variables name***
Input	Total employment
	Total energy consumption (electricity)
Output	Regional GDP
Non-desired output	general industrial solid waste
	total amount of emission for industrial waste gases
	total amount of discharge for industrial wastewaters

2.3 Data Source and China Regional Classification

This paper measures the ML index using provincial panel data of 30 provinces in mainland China during 2010-2020 (Tibet was not in the analysis system due to serious data deficiencies). The data are obtained from *China Statistical Yearbook*, *China Statistical Yearbook* of each province and city, *China Environmental Statistical Yearbook* and *China Environmental Yearbook*, and individual missing data are supplemented by interpolation method.

To study the level of high-quality development of China's regional economies, the authors divided China's provinces into four regions based on their geographical locations: Eastern, Central, Western and Northeastern, as shown in Table 2.

Table 2 Division of China s Economic Region

Region Name	***Province Name***
Eastern	Beijing, Hebei, Shanghai, Zhejiang, Jiangsu, Fujian, Shandong, Hainan, Guangdong, Tianjin;
Central	Shanxi, Jiangxi, Anhui, Henan, Hunan, Hubei;
Western	Inner Mongolia, Chongqing, Guizhou, Sichuan, Ningxia, Yunnan, Gansu, Guangxi, Qinghai, Shaanxi, Xinjiang;
Northeastern	Jilin, Liaoning, Heilongjiang.

3. Results & Discussion

In this paper, the authors measure the green-TFP of each province from 2011 to 2020 and divide them into regions to give the evaluation of economic quality development.

3.1 Analysis of the Results of High-quality Development in China's Province

Table 3 shows the average green-TFP and its decomposition index for each province in China for the years 2011-2020.

As seen in Table 3, the mean value of green-TFP in China's provinces is greater than 1, indicating that China's green productivity has improved during this decade. Looking at the provincial sample, the green ML of each province ranges from 0.944 to 1.118, with more than half of the provinces having a green ML greater than 1. Among all provinces, the best performer is Shanghai, followed by Jiangsu and Zhejiang, indicating that the eastern coastal region has the best effect on environmental protection in its economic activities. The next in the ranking are Beijing, Shandong and Tianjin, three provinces in the upper half of the Central Plains. The worst performers are Ningxia, Gansu and Xinjiang, which are located in the northwestern region of China and are lagging behind in economic development. Compared to other provinces, they are less committed to environmental protection and, to a certain extent, the economy is still being developed at the cost of the environment.

From the technical efficiency index of each province in Table 3, only 11 provinces in China have improved their technical efficiency, while the remaining provinces have deteriorated their efficiency to varying degrees. The best performer is Jiangsu, and the worst performer is Gansu. From the technical progress index, 20 provinces in China have a technical progress index greater than 1, which indicates that technical progress has generally occurred in all regions, with the best performance being in Shanghai and the worst performance being in Ningxia.

Table 3 Average Green-tfp and its Decomposition in 30 Provinces from 2011 to 2020

Name	***ML***	***ML EC***	***ML TC***	***Name***	***ML***	***ML EC***	***ML TC***
Beijing	1.033	0.978	1.056	Hunan	1.021	1.009	1.012
Tianjin	1.029	1.009	1.020	Inner Mongolia	0.966	0.977	0.989
Hebei	0.992	1.002	0.989	Guangxi	0.992	0.996	0.997
Shanghai	1.118	1.020	1.096	Chong qing	1.027	1.007	1.019
Jiangsu	1.067	1.031	1.035	Sichuan	1.023	0.984	1.040
Zhejiang	1.037	0.969	1.069	Guizhou	0.991	0.997	0.994
Fujian	1.011	0.956	1.058	Yunnan	0.983	0.978	1.005
Shandong	1.032	1.007	1.025	Shaanxi	0.971	0.972	0.998
Guang dong	0.974	0.964	1.010	Gansu	0.951	0.947	1.005
Hainan	0.966	0.978	0.989	Qinghai	0.957	0.948	1.010
Shanxi	0.979	0.997	0.983	Ningxia	0.952	0.973	0.978
Anhui	1.021	1.005	1.016	Xinjiang	0.944	0.961	0.981

Name	***ML***	***ML EC***	***ML TC***	***Name***	***ML***	***ML EC***	***ML TC***
Jiangxi	1.020	1.008	1.012	Liaoning	1.020	1.001	1.019
Henan	0.977	0.979	0.998	Jilin	1.012	0.994	1.018
Hubei	1.008	0.989	1.019	Heilong jiang	1.004	1.002	1.003

3.2 Overall Analysis of China's High Quality Development

As can be seen from Figure 1, in terms of time trend, China's green-TFP is smoothly upward, divided into two phases using 2017 as a node. In the first stage, the ML index oscillates slightly, which is mainly due to situations such as large fluctuations or sharp declines in total factor productivity in some provinces. In the second stage, the ML index rose steadily, during which the Chinese government strengthened environmental protection and formally put forward the requirement of high-quality economic development in 2017, influenced by the policy, provinces began to seek ways of development that maintain economic development while maximizing environmental protection, vigorously develop environment-friendly industries, actively encourage the use of new energy, and increase the investment in green enterprises. As a result, China's green-TFP rose steadily after 2017.

From the trend of MLEC and MLTC in Figure 1, the technical progress index is significantly higher than the technical efficiency index in most years, indicating that although the growth of total factor efficiency in China is the result of the combined effect of technical progress and technical efficiency improvement, the degree of technical efficiency improvement is still very limited, which restricts the growth of total factor efficiency, and if we want to progress to improve total factor production efficiency, we need to make more efforts in improving technical efficiency.

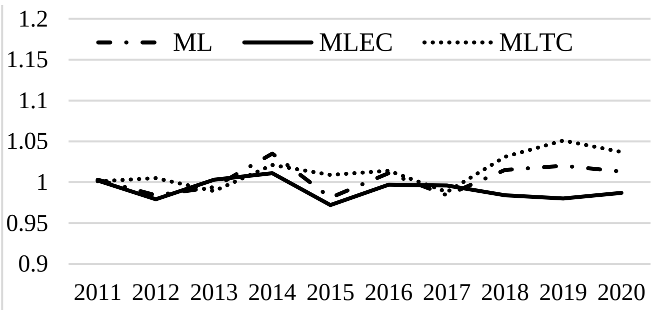

Figure 1 China's Green Total Factor Productivity 2011-2020

3.3 Analysis of Regional High Quality Development Differences in China

The paper divides China's provinces into four regions and discusses the changes in green-TFP in each of the four economic regions over a ten-year period. Details are shown in Figure 2.

Eastern region has the highest green total factor productivity: There are two reasons why the eastern region performs significantly better than other regions. From a macro perspective, the eastern region has the most developed economy, has a good business environment, allocates resources more efficiently, and can quickly respond to policy calls to achieve the transition from economic development to high quality economic development; from a micro perspective, enterprises in the region are under more competitive pressure, and they tend to get the highest output with the lowest input and produce in a more efficient manner, so the eastern region has the highest green-TFP.

Green-TFP in the Central Region has grown steadily. The Central Region ranked only third in green-TFP at the beginning, but gradually rose to second place after a decade of development. This is largely attributed to China's pursuit of a "dual circulation" development pattern for its economy, with increased investment and development in China's inland provinces. In addition, he development of Internet technology has made off-site offices a reality, with many companies moving away from the eastern region to choose the central region, where labor costs are lower. The Central Region has increased its own promotion and attracted a large number of talents to settle in the region, which has provided conditions for its high-quality economic development.

The green-TFP ranking of the rate in the northeastern region has regressed slightly. The provinces in the northeast do not have a habitable climate, which has led to a large brain drain and, in turn, a large number of businesses leaving. The rate of high-quality economic development is lower than that of the more populated eastern and central regions. However, in the time dimension, the northeastern region still has a small increase in green-TFP, mainly because the northeastern region is vigorously developing ecotourism industry, which brings economic growth to the region while protecting the environment.

Green-TFP in the western region needs to be improved. The green total factor productivity in the western region is volatile and low, mainly because the western region contains more provinces, both better performing ones, such as Chongqing, and worse performing ones, such as Xinjiang. The economic development of the western region is lagging behind, and the main goal of the region is still to develop the economy rapidly compared to developing environment-friendly industries.

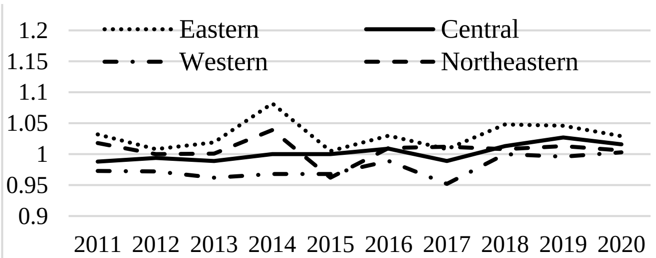

Figure 2 Green total factor productivity in different regions during 2011-2020

4. Conclusions

The paper uses green-TFP, which introduces non-desired outputs, to measure the level of high-quality development of China's regional economy. It is found that, first, China's overall total factor productivity has steadily improved over the past decade, especially after 2017, when policy objectives have become more focused on environmental protection and the economy has shifted to a high-quality development model. From the decomposition index, the technological progress index has improved significantly, while the technological efficiency index still needs further improvement; second, the eastern region of China has the highest level of high-quality economic development, while the western region lags behind the most. The eastern region has a better economic foundation, more concentrated industries, and rapid and faster response to economic transformation. The western region is more backward in economic development and faces greater pressure for economic development, and the protection of the environment needs to be strengthened. This paper puts forward suggestions to improve the quality development of regional economies in response to the research results.

4.1 Implementation of classification policies.

Provinces with low efficiency should not only increase the introduction, digestion, absorption and reinvention of production technology, take innovation as the first driving force of economic development, always implement the concept of innovation and development, which is the first of the five development concepts, and strive to promote high-quality development with the improvement of production technology based on comparative advantages, but also strengthen the collaboration between industry, academia and research and the transformation of scientific and technological achievements to improve the efficiency of production technology utilization. Provinces with continuous improvement in efficiency should develop targeted measures for the sources of efficiency improvement to promote high-quality development to a new level [6].

4.2 Strengthening Science and Ttechnology Innovation

Science and technology is the first productive force, in order to promote economic growth factor-driven to innovation-driven, we must increase support for enterprise innovation, stimulate enterprises to carry out technological innovation, formulate scientific development strategies, guide innovation resources to gather in enterprises, create an institutional environment conducive to scientific and technological innovation, encourage enterprises to increase their R&D income, establish a reward system for scientific research achievements, improve the mechanism for transferring scientific and technological achievements, and prompt enterprises to pendulumto overdependence on resources [7].

4.3 Cultivating High-Quality Talents

Talents, as resources with knowledge reserves and technical capabilities, can absorb and transform knowledge, technology and information through technological innovation spillover, promoting the increase of regional social knowledge stock, thus effectively promoting the transformation and upgrading of industrial structure and improving quality and efficiency for economic development [8]. Areas with better economic development can better meet people's needs for ecological environment, living standards, innovation and employment, and provide a carrier for various types of human resources to gather. Talent is an important guarantee for economic growth and efficiency improvement, and high-quality economic development is also the reason and direction for gathering talent and optimizing structure, both of which interact and influence each other.

4.4 Promoting Environment- friendly Industry Development

Improving the system of environmental governance for all people requires improving the list of government responsibilities, solidifying the foundation of the accountability mechanism for environmental governance, strengthening the government's environmental supervision of enterprises, continuously optimizing the way of environmental supervision, and compacting the responsibilities of governments at all levels [9]. Promote environmental information disclosure to provide the foundation for public participation. The development of green industries is an important measure to promote economic restructuring, and to promote enterprises' compliance with emission standards and transformation and upgrading.

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