ISSN: 2688-9323

Measurement of China's Green Total Factor Productivity and Analysis of its Influencing Factors

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Abstract

Based on the unexpected super-efficiency SBM model and the Malmquist index, the green total factor productivity (GTFP) of China from 2005 to 2019 was calculated under the constraints of resources and environment. The Theil index and its decomposition were used to investigate the regional differences of China's GTFP, and used the Tobit model to perform regression analysis on the 6 main factors affecting GTFP. The results show that China's GTFP is at a relatively low level as a whole, and the change in the mean value of GTFP from 2005 to 2019 is approximately " W -shaped". During the sample observation period, the overall difference of China's GTFP showed a cyclic fluctuation trend of rising first and then falling, and the regional differences were significant, showing the characteristics of east high and west low, intra-regional differences are the first source of overall differences in GTFP; ML index decomposition results show that the reason for China's GTFP improvement not only comes from technological progress, but also from the improvement of technical efficiency, and the east and middle, and the west have regional differences; further Tobit regression results show that environmental regulation, economic development level and technological innovation can promote the development of GTFP, and government R&D investment, human capital and opening to the outside world have negative effects on GTFP. From the perspective of space, the impact of opening up on the eastern, central and western regions is not significant, and other influencing factors are consistent with the overall results; The final robustness test further confirms the conclusion. Based on this, the government should vigorously promote the process of modernization, give full play to the role of innovation, and then promote the development of green total factor productivity and achieve high-quality economic development.

Keywords

Green Total Factor Productivity; SBM Model; Tobit Model.

1. Introdcction

At the meeting of the Political Bureau of the Central Committee of the Communist Party of China in July 2020, the general secretary emphasized the need to "accelerate the formation of a new development pattern with domestic circulation as the main body and domestic and international dual circulations promoting each other". The main "dual cycle" strategy, the driving force of economic growth has also begun to gradually change from investment-driven to total factor production efficiency. The same high-quality development also means green and sustainable development, and the increase in green total factor productivity (GTFP) has played an indispensable role in promoting the development of a green economy. Now that China is in a new economic normal, the key to China's future lies in green development, reducing the consumption of resources and environment, and improving green total factor productivity by improving green innovation capabilities. Under the background that the common development of China's regional economy has become the mainstream and the exchanges and cooperation between regions are more closely, discussing the influencing factors and spatial distribution characteristics of GTFP has important guiding significance for planning regional economic development and formulating relevant policies.

2. Literature Review

2.1. Definition and Measurement of Green Total Factor Productivity

Promoting green total factor productivity growth is an important means to achieve high-quality economic development now and in the future. Under the dual constraints of resources and environment, improving GTFP will promote resource allocation and utilization efficiency, and is the only way to achieve green development. Green total factor productivity is the integration of resources and environmental factors into productivity measurement in traditional total factor productivity analysis, and the input-output efficiency of energy consumption and pollution emissions is considered. It is an important indicator to achieve win-win development of regional green economy and environment.

For the measurement of green total factor productivity, the main methods in the current research are the data envelopment method (DEA) and the Solow value method. Chung et al. (1997) took environmental factors into account in the model and constructed the Malmquist - Luenberger index to measure GTFP, but they did not consider the slack variables of input and output, so the results were inconsistent with reality[1]. Tone (2001) first proposed a non-radial and non-angular SBM model, and made a more accurate calculation of GTFP considering the slack variable problem[2]. At the same time, domestic scholars have also conducted research on the calculation of GTFP. On this basis, Y. J. Yuan et al. (2015)[5], Y. F. Kuang et al. (2012)[4], Z. J. Yang et al. (2017)[8]used similar methods to evaluate China's industrial total factor productivity, environmental total factor productivity and Green total factor productivity is measured and related issues are analyzed. Z. Tan and X. Y. Wang (2016)[6]used the dynamic spatial panel model to analyze and found that distinguishing green bias and non-green bias plays a very important role in the improvement of green total factor productivity, and there are gaps in the impact of different biases on GTFP. W. B. Li and B. Liang (2017)[7]pointed out that there is a positive spillover effect of GTFP in China, and the effect is the most significant in the eastern region and the smallest in the western region.

2.2. Factors Affecting Green Total Factor Productivitty

Measuring green total factor productivity can reflect the green development level of a region, but how to achieve green development and how to promote the improvement of regional green development level is very important. Therefore, the multi-perspective exploration of its influencing factors has received mores concern.

At present, some scholars have found that the factors affecting green total factor productivity are relatively complex, and most of them are carried out from the aspects of economic development, opening to the outside world, environmental regulation, scientific and technological innovation, and industrial structure. F. Zhang (2017)[17]constructed Schumpeter's endogenous growth model to study the impact of China's financial development on GTFP, and found that financial development can promote the growth of total factor productivity and green total factor productivity at the same time. linear relationship. In terms of opening to the outside world, it mainly focuses on opening foreign direct investment (OFDI) and foreign direct investment (FDI). J. Zhang and Z. F. Li (2020) [[11]used the GMM model to study the impact of OFDI on GTFP and found that OFDI can significantly promote the development of GTFP, but with regional heterogeneity. But regarding the impact of FDI on GTFP, S. Ren and H. Zuo (2021)[19]came to the opposite conclusion, that is, FDI will inhibit the development of GTFP. The impact of environmental regulation on GTFP mostly revolves around

ISSN: 2688-9323

the "Porter Hypothesis" and neoclassical economics: W. G. Cai and X. L. Zhou (2017) [[9]proved that the impact of environmental regulation on GTFP presents an inverted "U"-shaped relationship with "Porter Hypothesis". Some scholars believe that environmental regulation has a certain threshold for promoting green total factor growth, but some scholars believe that environmental regulation will have a negative impact on G[10]. In terms of scientific and technological innovation, X. S. Li and Z. Y. Yu (2014) [[12]believed that scientific and technological progress can improve the level of green total factor productivity; the impact of human capital on GTFP cannot be ignored. Z. Tan and X. Y. Wang (2016) [6]pointed out that improving human capital and other soft technologies can effectively improve the absorption capacity of green technology efficiency. Most scholars have used different research methods to explore the impact of industrial structure on GTFP, and they have reached similar conclusions, that is, industrial structure has a significant positive effect on green total factor productivity, and has spatial heterogeneity [13][14][15]. Y. S. Liu et al. (2018) [16]used the ML index method and found that industrial structure upgrading, energy efficiency and their interaction can promote the development of green total factor productivity, and the promotion effect of industrial structure upgrading on green total factor productivity is greater than that of green total factor productivity. energy efficiency.

To sum up, the above literature has achieved fruitful results, but there is still room for progress: First, in terms of research objects, some scholars have measured total factor productivity based on radial and angular directional distance functions, ignoring bad outputs. Second, in terms of research methods, most of them use benchmark regression to analyze the influencing factors of green total factor productivity, ignoring that the GTFP index is greater than 0, which is a restricted variable. If OLS is used to regress the model, the results may be biased; Based on the non-radial SBM model, this paper incorporates both desirable and non-desirable outputs into the model to accurately measure China's GTFP level from 2005 to 2019. Influence factors such as economic development level and technological innovation are combined, and the Tobit model is introduced to discuss its impact on GTFP. impact effect, and study the spatial heterogeneity of green total factor productivity in various regions.

3. Measurement and Analysis of Green Total Favtor Productivity

3.1. Introduction to Measurement Methods and Modeld Super Sbm Model

By sorting out the references on green total factor productivity measurement, this paper adopts the slack variable problem proposed by Tone (2001) with the help of MAXDEA software, and comprehensively considers the input of energy resources during economic development based on the non-radial super-efficiency SBM model. And the problem of undesired output that has a negative impact on the environment to measure China's green total factor productivity. The specific model is as follows:

Among them, S_i^-, S_r^+, S_t^{b-}represent input, desirable and undesired slack variables, respectively, ρ represents the green total factor productivity of each DMU, m represents the number of input indicators, represents the number $q_1$of desirable and undesired output indicators, respectively, λ is the weight vector q_2.

$$min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{S_i^-}{x_{ik}}}{1-\frac{1}{q_1+q_2}(\sum_{r=1}^{q_1}\frac{S_r^+}{y_{rk}}+\sum_{t=1}^{q_2}\frac{S_t^{b-}}{b_{tk}})} \tag{1}$$

$$.t\begin{cases}\sum_{j=1,j\neq k}^{n} x_{ij}\lambda_j - S_i^- \leq x_{ik}\\ \sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + S_r^+ \geq y_{rk}\\ \sum_{j=1,j\neq k}^{n} b_{tj}\lambda_j - S_t^{b-} \leq b_{tk}\\ \lambda, S^-, S^+ \geq 0\\ i = 1,2\dots,m; r = 1,2\dots,q_1;\\ t = 1,2\dots,q_2; j = 1,2\dots,n(j\neq k)\end{cases} \tag{2}$$

3.2. Malquist Index and Decomposition

Different from the calculation result of the SBM model, the calculation result of the ML index changes dynamically, that is, the ML index constructs M (xt+1, yt+1, xt, yt) from the t period to the t+1 period. Based on the SBM distance function, this paper calculates the technical progress and technical efficiency of the ML index and further decomposition, and studies the reasons and dynamic trends of China's GTFP. The specific formula is as follows:

$$M(x^{t+1},y^{t+1},x^t,y^t) = \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \times \left[\frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})} \times \frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)}\right]^{\frac{1}{2}} = EC \times TC \tag{3}$$

Among them, x^{t+1}, y^{t+1}, x^t, and y^t represent the input and output of period t+1 and period t, respectively, $D^{t+1}(x^{t+1}, y^{t+1})$, $D^t(x^t, y^t)$ is the SBM distance function of the decision-making units in the t+1th and tth stages. In the formula, the ML index value represents the change rate of green total factor productivity between adjacent years, EC is the technical efficiency improvement index, and TC is the technological progress index. When ML>1, EC>1, TC>1, it means that GTFP increases from period t to period t+1, technical efficiency increases and technology progresses; otherwise, it decreases.

3.3. Indicataor Selection and Data Sources Indicator Selection

Based on the green total factor productivity measurement theory, this paper adds undesired environmental output factors to the output in order to highlight the concept of green development. Based on the input-output model, the measurement index system of China's green total factor productivity and various input-type and output-type indicators are determined as follows:

Input variables: three specific indicators use capital input, energy input and labor input to represent the degree of resource consumption by green development. Among the variables of capital input, the calculation of capital stock refers to the practice of H. J. Shan (2008) [18]2005 as the base period, using the perpetual inventory method to measure ($K_{i,t} = K_{i,t-1}(1-\delta_{i,t}) + I_{i,t}$), to estimate the capital stock from 2005 to 2019; labor the number of employees is selected as input; energy input is measured by total energy consumption (10,000 tons of standard coal).

Desirable output variable: In the output variable, the desired output selects the GDP of each province and city. Taking 2005 as the base period, the index deflator is performed to convert the constant price GDP of each province and city to eliminate the interference of price factors.

Undesirable output variables: Referring to the relevant literature in the past, this paper will use three pollutant emission indicators of industrial wastewater, industrial waste gas and industrial sulfur dioxide emissions to measure.

ISSN: 2688-9323

Based on the above discussion, this paper constructs a national green total factor productivity evaluation index system including three input variables, one expected output variable and three undesired output variables. The detailed index description is shown in Table 1.

Table 1. Input-output variable indicators

variable	first-level indicator	secondary indicators
input variable	capital investment	capital stock
	energy input	total energy consumption
	labor input	Number of employees
output variable	Desirable output	Constant GDP
	undesired output	Industrial wastewater COD
		Industrial waste gas SO2
		industrial waste

3.4. Data Sources

This paper studies the data of green total factor productivity indicators in 30 provinces and cities in China (except Tibet) from 2005 to 2019. Therefore, the panel data of 30 provinces and cities in China (except Tibet) from 2005 to 2019 are selected as the sample data comes from the "China Environmental Statistical Yearbook" and "China Statistical Yearbook", and some missing data are supplemented from the statistical yearbooks of various provinces and cities or imputed by interpolation.

3.5. Green Total Factor Productivity Analysis Analysis of Sbm Resulys

This paper uses the panel data of 30 provinces and cities in China from 2005 to 2019, and uses the MAXDEA software based on the Super-SBM model of unexpected output to measure the green total factor productivity of each province and city in the past 15 years, as shown in Table 2. It can be seen from Table 2 that China's GTFP is at a relatively low level, and there are few provinces and cities with green total factor productivity higher than 1 all year round. Guizhou, Qinghai, Ningxia and other places have all been below 0.5 in the past 15 years. attract attention.

By calculating the mean value of the whole country and the east, middle and west regions, the change trend is drawn as shown in Figure 1. As can be seen from Figure 1, the change of green total factor productivity in my country from 2005 to 2019 is approximately a "W"-shaped fluctuation, and the overall GTFP is at a relatively low level. The concept of development and building an environment-friendly society began to receive widespread attention. Therefore, China's green total factor productivity began to fluctuate in 2005, but due to the impact of the financial crisis in 2008, GTFP was in a state of fluctuation from 2008 to 2015. In 2015, the 18th National Congress of the Communist Party of China proposed the "Five Development Concepts" to realize the transition from high-speed economic development to high-quality development. After that, GTFP was in a stage of steady rise from 2016 to 2019, and the national green total factor productivity reached 0.523 in 2019.

Among different regions, the green total factor productivity of the three major regions of my country's east, middle and west is basically the same as the national change, approximately showing a "W"-shaped change. From the perspective of development level, the eastern GTFP is the highest and higher than the national average GTFP, followed by the central, and the western is the lowest, with significant regional differences. The eastern region mainly benefits from its own superior geographical advantages, development conditions and relatively advanced science and technology. The possible reasons why the GTFP in the central region is lower than the national average is due to its extensive development model, lack of resources and industries with insufficient competitiveness; the western region has developed relatively slowly due to its own geographical conditions, but in recent years, the country's "Western Region" The implementation of the "Great Development" strategy has promoted its economic development. After 2017, the GTFP in the western region has developed significantly.

Table 2. 2005-2019 China's Green Total Factor Productivity

	2005	2010	2015	2019
Beijing	1.056934	1.085352	1.084336	1.078976
Tianjin	0.77973	0.53263	0.460723	0.450302
Hebei	0.555975	0.423797	0.366562	0.37223
Shanxi	0.589384	0.406146	0.325035	0.342852
Inner Mongolia	0.521342	0.43768	0.394661	0.411852
Liaoning	0.587563	0.474688	0.43465	0.453763
Jilin	0.588509	0.345287	0.340876	0.343738
Heilongjiang	1.013945	0.546053	0.459714	0.45815
Shanghai	1.145957	1.078753	1.088739	1.091849
Jiangsu	0.817671	0.762117	0.77167	0.784433
Zhejiang	0.81903	0.75152	0.72798	0.723889
Anhui	0.777396	0.638545	0.563292	0.53941
Fujian	0.872324	0.712729	0.660391	0.643815
Jiangxi	0.657259	0.587968	0.55983	0.557924
Shandong	0.612945	0.497141	0.481631	0.496907
Henan	0.706871	0.513354	0.47207	0.494507
Hubei	0.705413	0.568676	0.54126	0.526787
Hunan	1.05994	0.567976	0.540799	0.556775
Guangdong	1.365689	1.088058	0.819291	0.760324
Guangxi	1.012916	0.437838	0.376264	0.381471
Hainan	1.121312	0.626151	0.474303	0.452945
Chongqing	0.629243	0.588241	0.662411	0.656233
Sichuan	0.618805	0.533475	0.531078	0.52599
Guizhou	0.440929	0.411553	0.352411	0.334149
Yunnan	0.596063	0.482964	0.388327	0.370119
Shaanxi	0.667422	0.489638	0.43927	0.429169
Gansu	0.508559	0.446493	0.384492	0.400603
Qinghai	0.428271	0.372916	0.287057	0.274966
Ningxia	0.400897	0.277173	0.251568	0.451772
Xinjiang	0.557802	0.463687	0.333149	0.313027

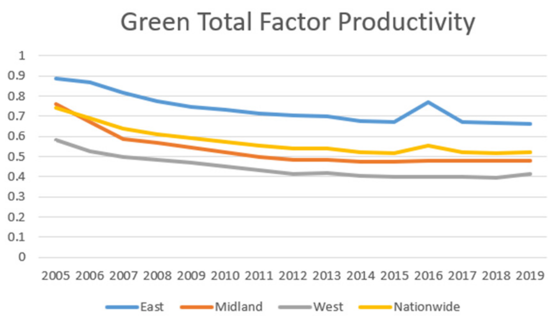

Figure 1. Changes in mean values across the country and in the East, Central and West regions

4. Malmquist Index and Decomposition

Static value of GTFP in China every year is calculated by the SBM model in the previous article, and the dynamic change index of China's green total factor productivity in the next two years is calculated by the Malmquist index. At the same time, the Malmquist index is decomposed into technical efficiency change index and technological progress index. Therefore, according to the MAXDEA software, this paper measures and analyzes the GTFP and its decomposition items technical efficiency (EC) and technical progress (TC) in various provinces and cities across the country through the Malmquist index. The results are shown in Table 3.

Table 3. National Average ML Index and Decomposition

	province	Malmquist Index	EC	TC
East area	Beijing	1.0965	1.0353	1.0591
	Tianjin	0.9682	0.9621	1.0063
	Hebei	0.9766	0.9721	1.0046
	Liaoning	0.9896	0.9822	1.0075
	Shanghai	1.0143	0.9968	1.0176
	Jiangsu	1.0072	0.9971	1.0101
	Zhejiang	1.0025	0.9913	1.0113
	Fujian	0.9801	0.9787	1.0014
	Shandong	0.9950	0.9855	1.0096
	Guangdong	0.9844	0.9611	1.0242
	Hainan	0.9503	0.9411	1.0098
	Eastern average	0.9965	0.9821	1.0147
Central Region	Shanxi	0.9670	0.9629	1.0043
	Jilin	0.9677	0.9640	1.0038
	Heilongjiang	0.9484	0.9482	1.0002
	Anhui	0.9750	0.9748	1.0002
	Jiangxi	0.9919	0.9885	1.0034
	Henan	0.9757	0.9754	1.0003
	Hubei	0.9801	0.9799	1.0002
	Hunan	0.9676	0.9617	1.0061
	central average	0.9716	0.9694	1.0023
Western Region	Inner Mongolia	0.9917	0.9837	1.0081
	Guangxi	0.9375	0.9366	1.0010
	chongqing	1.0105	1.0034	1.0071
	Sichuan	0.9893	0.9887	1.0006
	Guizhou	0.9847	0.9806	1.0042
	Yunnan	0.9673	0.9668	1.0005
	Shaanxi	0.9702	0.9693	1.0009
	Gansu	0.9854	0.9834	1.0020
	Ningxia	0.9727	0.9691	1.0037
	Qinghai	1.0312	1.0265	1.0046
	Xinjiang	0.9674	0.9599	1.0078
	Western average	0.9825	0.9789	1.0037
	total average	0.9847	0.9776	1.0073

Table 3 shows the regional differences and their decomposition of G TFP in various provinces and cities across the country. On the whole, China's ML index is at a low level, showing a downward trend in general, with an average decrease of 2.24% in EC, but an average increase in TC by 0.73%. On the whole, the ML index of the six provinces and cities of Beijing, Shanghai, Jiangsu, Zhejiang, Chongqing and Qinghai is greater than 1, indicating that these six provinces and cities have strong comprehensive strength and higher economic development level than other provinces and cities. The lower production level is on the frontier. Among them, Beijing's ML index increased by 9.65% on average, EC increased by 3.53% on average, and T C increased by 5.91%, all of which were the largest in the same period, indicating that Beijing 's green economy development effect is the most significant. Among the 30 provinces and cities in the country (except Tibet), the maximum value of ML index is Beijing (1.0965), and the minimum value is Guangxi (0.9375), indicating that there are still large differences in GTFP in different regions. In terms of sub-regions, the ML index in the eastern region is the largest at 0.9965, followed by the central region and the smallest in the western region. Comparatively speaking, the GTFP in the eastern region has increased significantly. In terms of technological progress (TC), the national average TC from 2006 to 2019 was 1.0073, indicating that the national technological progress increased by 0.73%. In contrast, the average technical efficiency EC is only 0.9776, and the EC in the eastern, central and western regions are all less than 1, indicating that China still has a lot of room for improvement in technological progress. Through the decomposition of GTFP in various provinces, it can also be found that the reasons for its improvement come not only from technological progress, but also from the improvement of technical efficiency.

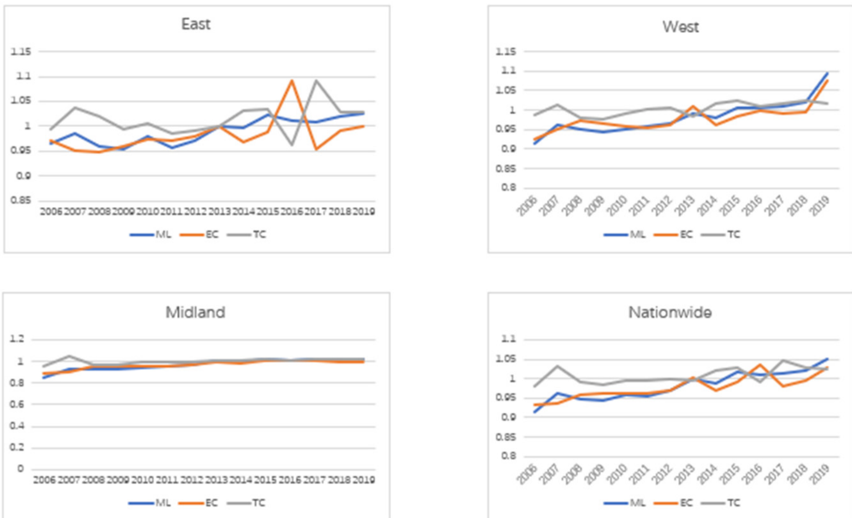

Figure 2. Nationwide, East, Middle and West G TFP and its decomposition

It can be seen from Figure 2 that my country's green economic efficiency has an increasing trend. On the whole, except for a few years, the change trend of China's overall ML index is consistent with that of EC, indicating that the change of China's GTFP mainly comes from the improvement of technical efficiency. Among different regions, the change trend of GTFP in the eastern region from 2006 to 2013 is consistent with technological progress. With the continuous progress of technology, the change of GTFP after 2013 mainly comes from technical efficiency. The ML index in the central region is completely consistent with EC and TC, and both fluctuate around 1. That is to say, the change in GTFP in the central region is partly due to the improvement of technical efficiency, and the other part is due to technological progress. In the western region, TC is always 1, and the change trend of ML index is completely consistent with that of EC, indicating that the change of GTFP in the western region mainly comes from technical efficiency. It can be seen that there are strong spatial differences in the changes of GTFP in China.

5. Regional Differences and Decomposition

The Theil index can be used to measure the contribution of the intra-group gap and the inter-group gap to the total gap. Therefore, this paper calculates the overall, intra-regional and inter-regional differences in China based on the Theil index and its decomposition. The results are shown in Figure 3: It can be seen that the differences in GTFP in the three major regions of the east, the middle and the west are the first source of the overall differences in China's GTFP. During the sample observation period, from the perspective of the time evolution trend, the overall difference of China's GTFP showed a cyclic fluctuation trend of rising first and then decreasing, indicating that there were obvious regional differences in China's GTFP, and the intra-regional differences basically maintained the same development as the overall differences. It reached a peak in 2016 and then maintained a downward trend as a whole; from the perspective of the difference, the contribution rate of inter-regional differences increased from 32.33% in 2005 to 34.83% in 2019, while the intra-regional contribution rate increased from 2005 to 32.33%. From 67.67% in 2019 to 65.17% in 2019, it shows that the influence of intra-regional and inter-regional differences on the overall difference remains basically unchanged; from the perspective of the contribution rate of regional differences, intra-regional differences are the main cause of the regional development of China's GTFP, the average contribution rates within and between regions are 65.17% and 34.83% respectively. It can be seen that the difference within the region accounts for a large proportion of the overall difference in GTFP, indicating that the key to promoting the coordinated development effect of China's green economy lies in how to promote the three major eastern, central and western regions in China. Balanced development of GTFP in the region.

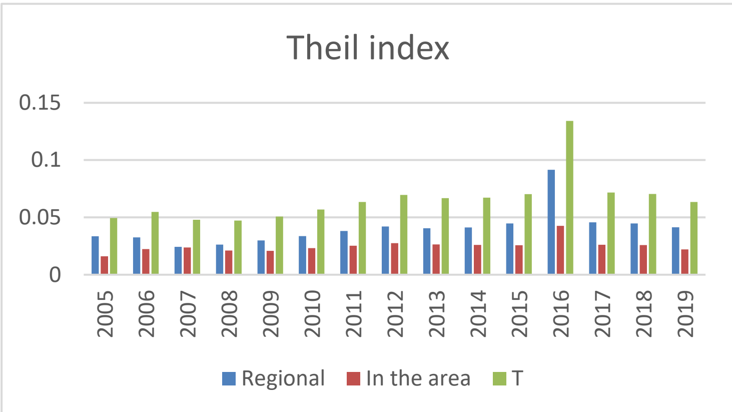

Figure 3. Overall difference

6. Analysis of Empirical Results of Influencing Factors of Green Total Factor Productivity

6.1. Introduction to Tobit Model Theory

Based on the super-efficiency SBM method to measure the green total factor productivity, it is concluded that the value range of the ML index is greater than 0, which belongs to the "restricted dependent variable", and the regression results of the model may be biased if OLS is used. Therefore, this paper selects the Tobit model to empirically study the impact of various influencing factors on GTFP. The Tobit model formula is:

$$Y_{it}^{*} = \alpha + \beta X_{it} + \mu_{it} \tag{4}$$

$$Y_{it} = \begin{cases} 0 & Y_{it}^* \leq 0 \\ Y_{it}^* & Y_{it}^* > 0 \end{cases} \quad (5)$$

In the formula, $Y_{it}^*$is the dependent variable, that is, the green total factor productivity of each province and city in each year, X_{it} is the main factor affecting the green total factor productivity, α is a constant term, β is a regression coefficient vector, and μ is a random interference term.

6.2. Variable Selection and Data Interpretation Variable Selection

Combined with the previous analysis, the green total factor productivity calculated above is selected as the explained variable; this paper draws on the existing research and selects environmental regulation (er), economic development level (gdp), technological innovation (tech), government R&D investment (rd), human capital (edu), and opening to the outside world (open) as explanatory variables. The specific description of each influencing factor is shown in the Table 4:

Table 4. Variable definitions

variable type	variable name	Variable meaning	Calculation
dependent variable	GTFP	green total factor productivity	SBM function based on undesired output
Explanatory variables	er	Environmental regulation	the ratio of government environmental expenditure to total fiscal expenditure
	gdp	economic development	Logarithmic GDP per capita
	tech	Technological innovation	Number of patents filed
	rd	government R&D investment	Fiscal technology spending
	edu	Human capital	Years of education per capita
	open	Opening to the outside world	the proportion of total import and export to regional GDP.

6.3. The Data Shaows

The above data are all from the website of the National Bureau of Statistics and the statistical yearbooks of various provinces and cities. The data interval is 2005-2019. To eliminate possible dimensional effects, all variables are logarithmic in model estimation.

6.4. Tobit Empirical Results Analysis

Since the measured green total factor productivity is greater than 0, showing a left-tailed distribution, the regression analysis using traditional regression methods such as OLS may result in deviations in the results. Therefore, this paper selects the restricted variable model Tobit model for empirical analysis, and the national, the eastern region, the central region and the western region were used as samples for analysis using Stata software, and the results are shown in Table 5.

From the regression results of the whole country, the regression coefficient of economic development level is positive, and it is 0.6 at the 1% significance level, indicating that the improvement of economic development level has a strong driving effect on China's GTFP. With the improvement of economic level, the government, enterprises and individuals pay more and more attention to the development of green and low-carbon economy, and the awareness of environmental protection has gradually increased, making the economy change from the original extensive development to green and intensive development, reducing environmental pollution and resource waste; environmental regulation promotes. The improvement of China's GTFP is significant at the 10% significance level, that is, environmental protection policies may promote technological innovation or the adoption of innovative technologies by enterprises, so as to improve the production efficiency of enterprises, promote economic growth, and then Improve China's green total factor productivity; at the level of technological innovation, its coefficient is 0.012, and it has passed the 5% significance test, that is, technological innovation promotes the development of green total factor productivity, indicating that with the improvement of scientific research level, the overall science and technology can be improved. The level of innovation is to fundamentally transform the economic development model through green technology, promote resource-saving and environmentally friendly new ecological industries, reduce resource waste and environmental pollution , and promote the development of green economy; in terms of government R&D investment, its impact on GTFP is significantly: Negative, the possible reason is that due to the intervention of the local government, the local government may tend to use coercive administrative means to force enterprises to carry out environmental governance, resulting in the distortion of resource elements, which is not conducive to the improvement of GTFP; the human capital effect is significant but the coefficient is negative value, indicating that human capital inhibits the growth of green total factor productivity, similar to the findings of Benhabib and Spiegel (1994) [3], who showed that human capital as a direct input factor has no significant effect on green total factor productivity; The negative effect is significant, indicating that opening to the outside world will bring foreign capital investment and development opportunities, and will also bring competitive pressure to local development with the influx of foreign goods and services, hinder the process of economic development, and inhibit the growth of green total factor productivity develop.

Table 5. Tobit regression results

variable	National	east	Central	west
ler	0.010*	0.009*	0.005	0.014
	(0.10)	(0.09)	(0.584)	(0.412)
lgdp	0.600***	0.237*	1.564***	0.657***
	(0.00)	(0.10)	(0.00)	(0.006)
ltech	0.012**	0.020**	-0.001	0.018*
	(0.03)	(0.023)	(0.941)	(0.071)
lrd	-0.016*	-0.015**	-0.033*	-0.024**
	(0.08)	(0.02)	(0.10)	(0.043)
ledu	-0.103**	0.020	-0.301**	-0.198*
	(0.02)	(0.673)	(0.015)	(0.091)
lopen	-0.007*	-0.004	-0.01	-0.006
	(0.08)	(0.527)	(0.434)	(0.597)
_cons	-0.249	0.259	-1.877***	-0.194
	(0.234)	(0.351)	(0.001)	(0.64)
sigma_e	0.059***	0.042***	0.048***	0.077***
	(0.00)	(0.00)	(0.00)	(0.00)
N	450	165	120	165

From a spatial perspective, environmental regulation has a positive impact on the eastern, central and western regions of China, but the coefficients in the central and western regions have not passed the significance test, indicating that environmental regulation in the central and western regions of China has no significant impact on GTFP. The economic development level of the eastern, central and western regions of China has a positive coefficient of influence on green total factor productivity, which is significant at the 10% and 1% significance levels respectively, which is consistent with the overall estimate, of which the coefficient in the central region is 1.44, the effect is the most significant. The possible reason is that compared with the eastern region, the GTFP in the central region still has a higher room for improvement, so it has a higher growth trend under the promotion of economic development. In terms of technological innovation, the regression coefficients in the eastern and western regions are greater than 0, but the estimated coefficients in the central region are negative and insignificant. Government R&D investment did not improve green total factor productivity. The possible reason is that the government invested less in green and clean production of enterprises and more in production technologies that would bring high profits. In the eastern, central and western regions, human capital has an inhibitory effect on green total factor productivity. The possible reason is the lack of high-tech talents in China, and a large amount of investment in the financial field has led to the lack of high-tech talents for the development of green economy, which is not conducive to the development of GTFP. The estimated coefficient of China's opening to the outside world is negative in the eastern, central and western regions, which is consistent with the overall estimated results of the country, but it has not passed the significance test.

6.5. Robustness Check

In order to test the robustness of the model, in this paper, the explained variables and explanatory variables are tailed at the 1% level to test the robustness of the impact of each influencing factor on green total factor productivity. The Tobit regression results are as follows:

Table 6. Robustness check

variable	National	east	Central	west
ler	0.005	0.007	0.006	-0.006
	(0.217)	(0.217)	(0.512)	(0.434)
lgdp	0.472***	0.242*	1.44***	0.328**
	(0.00)	(0.081)	(0.00)	(0.076)
ltech	0.018**	0.022**	-0.001	0.038***
	(0.00)	(0.02)	(0.915)	(0.00)
lrd	-0.019***	-0.019*	-0.028*	-0.039***
	(0.004)	(0.1)	(0.10)	(0.00)
ledu	-0.08**	0.020	-0.273**	-0.073
	(0.021)	(0.661)	(0.025)	(0.33)
lopen	-0.006*	-0.005	-0.01	-0.006
	(0.035)	(0.424)	(0.435)	(0.346)
_cons	-0.034	0.247	-1.666***	0.221
	(0.822)	(0.346)	(0.004)	(0.486)
sigma_e	0.038***	0.039***	0.046***	0.029***
	(0.00)	(0.00)	(0.00)	(0.00)
N	450	165	120	165

As shown in Table 6, from a national perspective, the coefficients of environmental regulation, economic development level, technological innovation, government R&D investment, human resources, opening to the outside world, and green total factor productivity are abbreviated by 1%. The signs are consistent and the 1% significance test is passed. In addition, the signs of the regression coefficients in the east, middle and west are consistent with the above model, and

ISSN: 2688-9323

the significance level and coefficient value have not changed significantly. Therefore, the above results show that the results of the model constructed in this paper are robust.

7. Conclusions and Policy Recommendations

7.1. Conclusion

Based on the unexpected super-efficiency SBM model, this paper calculates China's green total factor productivity from 2005 to 2019 under resource and environmental constraints, and uses Malmquist index and Theil index to decompose the regional differences of China's GTFP, and finally uses the Tobit model to explore influencing factors and mechanism of action of GTFP. And from the perspective of sub-regions, the regional heterogeneity of the influencing factors in the eastern, central and western regions of my country is studied. The research results show that: First, China's GTFP is at a low level, and the change in the mean value of GTFP during the sample observation period is approximately "W-shaped". In terms of development level, the eastern region is the highest, the central region is the second, and the western region is the smallest, with significant regional differences; Second, according to the decomposition of the ML index, China's green total factor productivity shows a downward trend, and China's green total factor productivity is in the eastern region > the central region > the western region. From the decomposition index, the growth of China's GTFP is mainly affected by the efficiency of green technologies, which can be divided into two stages: GTFP from 2005 to 2013 was mainly affected by technological progress, and technical efficiency improved after 2013 This greatly affects the green total factor productivity. From the perspective of spatial distribution, the GTFP in the eastern region of China is mainly affected by technical efficiency; The GTFP change in the central region is partly due to the improvement of technical efficiency, and the other part is due to technological progress; While the GTFP change in the western region is due to technical efficiency; Third, regional difference analysis shows that there are significant differences in the regional development of GTFP in China, and the differences in the development of GTFP in the three regions of the east, the middle and the west are the main factors that cause the overall regional GTFP in China. From the perspective of the contribution rate of regional differences, intra-regional differences are the main cause of the regional development of GTFP in China, indicating that the key to promoting the coordinated development effect of China's green economy lies in how to promote the balanced development of GTFP in the three major regions of China. Fourth, the regression results of the Tobit model show that environmental regulation, economic development level, and technological innovation have a significant positive role in promoting the development of GTFP; government R&D investment, human capital, and opening to the outside world have inhibited the development of GTFP. In terms of sub-regions, the impact of environmental regulation on the eastern region is consistent with that in the whole, but the impact on the central and western regions is not significant. The economic development level and government R&D investment have the same impact on each region as the whole. The regression coefficient of technological innovation to the central region is negative but fails the significance test. Human capital has a significant inhibitory effect on the improvement of green total factor productivity in the central and western regions, but has no significant effect on the development of GTFP in the eastern region. At the same time, opening to the outside world has no significant effect on promoting the development of green total factor productivity in the eastern, central and western regions.

7.2. Suggestion

The first is to increase investment in environmental governance and promote the construction of ecological civilization. Support high-tech enterprises with low pollution, high energy efficiency and strong market competitiveness. For heavy polluting enterprises with high energy consumption and no market competitiveness, targeted measures should be taken to promote

ISSN: 2688-9323

industrial upgrading. The government should handle the funds in compliance, accurately implement the use of funds, and ensure that the funds are in place. At the same time, the government should also strive to fulfill the task requirements of reducing costs, destocking, and reducing production capacity, clearing the policy system faced by production factors such as capital, labor, and energy, and providing a sustainable development environment for the allocation of factors, so as to effectively improve green total factor productivity.

The second is to focus on scientific research investment and improve the endogenous power of green total factor productivity. The government should further increase investment in science and technology, human and material resources, speed up the research and development of environmental protection technologies, and improve the ability of environmental governance, so as to achieve the improvement of green total factor productivity. In addition, the government must actively provide facilitation, financial support, and tax reduction policies for the scientific and technological research and development of enterprises, which can better reduce the cost of scientific and technological research and development of enterprises and create a good environment for technological research and development and innovation. Further improve the construction of infrastructure, especially those with low pollution and low energy consumption, and at the same time speed up the construction of inter-regional transportation networks, promote the circulation of factors between regions, and accelerate green development.

Third, the impact of opening to the outside world on green total factor productivity is negative and significant, which to a certain extent shows that my country should improve the quality and efficiency of foreign investment while improving opening to the outside world. Promote further cooperation between my country and other countries in some new fields, create a venture capital cooperation mechanism, and build a new blueprint for foreign trade. By adjusting taxation to encourage enterprises to export and improve international competitiveness. Subsidize the introduction of cutting-edge technologies to encourage imports, encourage companies to introduce external high-tech technologies, eliminate a number of companies or technologies with high costs, low benefits and high pollution, inject fresh blood into domestic companies, and contribute to the sustainable development of green total factor productivity provide new impetus.

The fourth is to firmly promote regional integration and promote regional linkage development. To promote the development of my country's overall green total factor productivity, we must first break the regional restrictions, gradually improve the construction of transportation infrastructure networks in various provinces and cities, and lay the foundation for the flow of production factors between regions. For neighboring provinces, by improving exchanges and cooperation between neighboring provinces, especially those with similar structures and economic foundations; at the same time, data sharing can be adopted to narrow the gap between the two regions. The government should not only stimulate the eastern coastal areas as well as the spatial spillover effect of developed provinces, it will drive backward peripheral provinces; it is also necessary to construct a good spatial spillover platform to highlight the connecting role of the central region.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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