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Research on the Measurement and Spatial Spillover Effects of Green Total Factor Productivity in Western Regions

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Abstract

Green total factor productivity emphasizes the progress of technology and the improvement of factor input efficiency. The western region is an important ecological barrier in China, and more attention should be paid to green development. Firstly, the paper selects the panel data of 12 provinces in western China from 2007 to 2020, and measures their green total factor productivity and its decomposition factors using the EBM model and GML index. Based on this, the paper selects control variables such as industrial structure, government behavior, economic development level, foreign investment and scientific research investment, and uses the spatial Durbin model to study the spillover effect of green total factor productivity in western China, it was found that the driving force of green total factor productivity in the western region to promote the economy mainly comes from the efficiency of green technology. Foreign investment has a positive effect on it, while government behavior is opposite to the level of economic development, and the industrial structure has a positive spillover effect on it, while the level of economic development is opposite. Therefore, suggestions have been put forward to improve the level of green technology, promote industrial structure upgrading, and focus on the quality of foreign investment introduction, in order to provide reference for the development of green total factor productivity in the western region.

Keywords: western region, green total factor productivity, Spillover effect, Spatial Durbin model

1. Introduction

Since the reform and opening up, China's economy has achieved rapid development, but with it comes waste of resources and environmental damage. In order to better ecological and sustainable development, people have begun to focus on green development, in order to promote high-quality economic development. In the 1950s, some economists proposed using Total Factor Productivity (TFP) to measure the economic development status of a country or region. However, traditional TFP indicators often overlook the impact of resource and environmental constraints on economic development, which cannot objectively and accurately reflect economic growth issues. In order to cater to the current situation of resource depletion and environmental degradation, resource and environmental constraints have been added to traditional total factor productivity, resulting in the generation of Green Total Factor Productivity (GTFP). The improvement of green total factor productivity is based on high-quality economic development, continuous technological progress, and improvement of factor input efficiency in a country or region. Therefore, research on improving green total factor productivity is of great significance.

The western region is not only a major ecological functional area in China, but also a major ethnic minority gathering area. In order to maintain ethnic unity and national security, China implemented the Western Development Strategy in 2000. After more than 20 years of development, the economy of the western region has made significant progress, but the rapid economic development has also gradually expanded the differences between regions. The western region has always been a vulnerable group in China's economic development, It mainly relies on the investment of resources to promote economic development, followed by gradually severe resource depletion and environmental problems. The way to develop the economy at the cost of sacrificing the ecological environment cannot maintain sustainable economic development, especially in the stage of green transformation of economic development in China. Green development is a necessary condition for promoting the healthy development of the western economy and an important way to promote harmonious coexistence between humans and nature. In May 2020, the central government issued the "Guiding Opinions on Promoting the Western Development and Forming a New Pattern in the New Era", which pointed out that to accelerate the green development of the western region, green transformation and development are the key to the coordinated and orderly economic and social development of the western region in the new era. The development of the western region must always practice the concept that green waters and mountains are the golden mountains and silver mountains. As a key ecological functional area in China, the western region is an important ecological barrier and should actively build a green development ecosystem to contribute to the high-quality development of China's economy.

This article adopts a spatial econometric model to calculate and analyze the green total factor productivity of 12 provinces in the western region from 2007 to 2020. Finally, the spillover effects of various indicators on the green total factor productivity of the western region are analyzed, in order to make certain contributions to improving the research on the green total factor productivity of the western region through spatial geographical location.

2. Literature Review

The measurement methods of green total factor productivity can be divided into parametric methods mainly based on Solow residual method and non parametric methods mainly based on Data envelopment analysis according to different determination methods of production frontier. The Solow residual method was first proposed by Solow in 1957. Solow believed that total factor productivity is the growth rate [1] generated by subtracting input factors from the total production growth rate. Later, Denison divided the input factors in more detail based on the Solow residual method, making the results of the Solow residual method more accurate. Zhang Hao, Zhang Jianhua, et al. (2016) measured the total factor productivity of 242 prefecture level cities in China based on the Solow residual method, and found that there is [a] spatial spillover effect in urban total factor productivity. Zhou Yongfeng (2018) used the Solow residual method to calculate China's total factor productivity from 1991 to 2015, and found that the average growth rate of China's total factor productivity was less than 0.4. Yang Wenpu, Zeng Huifeng, et al. (2022) used the Solow residual method to calculate total factor productivity, analyzed the impact mechanism of the digital economy on total factor productivity, and found that the digital economy has a significant positive effect on total factor productivity.

James and Cooper are the first people who proposed Data envelopment analysis. They used Data envelopment analysis [6] when studying the relative efficiency of production methods with multiple inputs and multiple production pollutants. Sun Jinling et al. (2019) used the SBM model and Malmquist productivity method to measure the total factor productivity and green economic efficiency of provinces in the "the Belt and Road" area. Feng et al (2019) also used the DEA-Global Malmquist index to measure the green total factor productivity of the Chinese metal industry from 2000 to 2015, and found that the overall green total factor productivity of the Chinese metal industry is in an upward trend. Li Kaifeng et al. (2022) used the SBM model and Malmquist index to measure the green total factor productivity of the Yellow River Basin in China from 2008 to 2017, and found that the increase and change in green total factor productivity in the upper reaches of the Yellow River Basin were the most significant. Zhang Aoxiang and Deng Rongrong (2022) also used the DEA model and Malmquist index [10] when studying the impact of digital inclusive finance on agricultural green total factor productivity.

In order to gain a deeper understanding of green total factor productivity, many scholars have gradually begun to study various factors that affect green total factor productivity. Li Lian (2021) studied the green total factor productivity and its influencing factors of 14 prefecture level cities in Liaoning Province from 2003 to 2018, and found that foreign investment can effectively promote the improvement of green total factor productivity, while industrial structure and government expenditure can suppress green total factor productivity. Zhao Dan (2021) selected data from 30 provinces and cities in China (excluding Tibet) from 2003 to 2017, and used DDF and GML indices to calculate the green total factor productivity of each region. The research and analysis showed a positive relationship between urbanization level and green total factor productivity of provinces in China, with no significant impact on industrial structure and human capital level. Wu Jing et al. (2022) analyzed the impact of the digital economy on green total factor productivity and found that the development of the digital economy has direct and spillover effects on improving green total factor productivity. Wang Yun et al. (2019) analyzed the impact of tightening environmental policies on the green total factor productivity of national industrial sectors. The results showed that at a certain level, environmental regulations can promote the improvement of green total factor productivity, but beyond a certain value, it will have a reverse effect.

Through a review of the methods for measuring green total factor productivity and their influencing factors, it was found that many scholars have gradually improved their research on total factor productivity. However, there is relatively little literature on green total factor productivity in terms of spatial and geographical location, especially in the study of green total factor productivity in the western region of China. Therefore, this article determines the research direction.

3. Measurement and Analysis of Green Total Factor Productivity in Western Regions

3.1 Data Source

This paper selects the panel data of 12 provinces in the western region from 2007 to 2020 to study the spillover effect of green total factor productivity in the western region. The data comes from China Statistical Yearbook, China Environmental Statistical Yearbook, China Energy Statistical Yearbook, the statistical yearbooks of 12 provinces in the western region, the National Bureau of Statistics and the statistical bureaus of each province. At the same time, some missing data are supplemented by interpolation.

3.2 Indicator Selection

Green total factor productivity indicators are divided into input indicators and output indicators. Input indicators include labor input, capital input, and energy input, while output indicators include expected output and unexpected output.

Labor input: Labor input refers to the actual input of labor in the production process, including labor quality, total labor volume, labor efficiency, etc. Given that there is limited data on the existing labor income mechanism in China, and in existing literature, the vast majority of scholars use the number of employees when measuring labor input. This article uses the number of employees in various provinces in the western region to measure labor input, The unit is set at 10000 people.

Capital investment: In the existing literature, some scholars choose capital stock to measure capital investment. However, due to the different choice of base period, the estimated capital stock has certain differences. In this paper, fixed assets investment of the whole society is selected as the index to measure capital investment, and the unit is set at 100 million yuan.

Energy input: Energy input is a type of intermediate consumption and the main source of pollution emissions. This article selects electricity consumption as a measure of energy input, with a unit set at 100 million kilowatt hours.

Expected output: Expected output usually refers to the "good" part of the output of the decision-making unit, and the gross domestic product of a region to a certain extent reflects the economic development level of the region. Therefore, this article uses the regional gross domestic product of each province in the western region to represent the expected output. In order to more accurately reflect the state of economic development, the actual GDP of 12 provinces in the western region is calculated based on 2006, with the unit set at 100 million yuan.

Unexpected output: unexpected output refers to "bad" output other than expected output, which mainly involves relevant indicators of environmental pollution. In this paper, chemical oxygen demand emissions and sulfur dioxide emissions are selected as indicators to measure unexpected output, and the unit is set to 10000 tons.

3.3 EBM-GML Model

In existing models, the traditional DEA model ignores the issue of slack variables, and the projection point of the evaluated DMU in the SBM model is farthest from the front. On the one hand, the EBM model solves the problems existing in traditional DEA and SBM models, and on the other hand, it takes into account unexpected outputs. The expression for the non directional EBM model is as follows:

$$\gamma^* = min\frac{\theta-\varepsilon_x\sum_{i=1}^{m}\frac{\sigma_i^-\mu_i^-}{x_{ip}}}{\beta-\varepsilon_y\sum_{j=1}^{n}\frac{\sigma_j^+\mu_j^+}{y_{jp}}+\varepsilon_z\sum_{l=1}^{q}\frac{\sigma_l^{z-}\mu_l^{z-}}{z_{lp}}} \quad (1)$$

s.t.

$$\sum_{w=1}^{s} x_{iw}\delta_w + \mu_i^- - \theta x_{ip} = 0, i = 1,2,\cdots,m \quad (2)$$

$$\sum_{w=1}^{s} y_{jw}\delta_w - \mu_i^+ - \beta y_{jp} = 0, j = 1,2,\cdots,n \quad (3)$$

$$\sum_{w=1}^{s} z_{lw}\delta_w + \mu_l^{z-} - \beta z_{lp} = 0, l = 1,2,\cdots, (4) \quad \delta_w \geq 0,\ \mu_i^-,\ \mu_j^+,\ \mu_l^{z-} \geq 0$$

Among them, γ^* is the optimal efficiency value, and $\gamma^* \in [0,\ 1]$, γ^* when it is 1, it indicates that the decision-making unit technology is effective; M represents the quantity of inputs, n represents the quantity of expected outputs, and p represents the quantity of unexpected outputs;

x_{ip}, y_{jp}, z_{jp}, representing respectively the p-th input, expected output, and unexpected output of the i-th decision-making unit; μ_i^- refers to the relaxation amount of the i-th input, μ_i^+ refers to the relaxation of the jth expected output, while μ_i^{z-} refers to the relaxation amount of the l type of non expected output; δ represents a weight vector; σ_i^- refers to the indicator weight, and $\sum_{i=1}^{m}\sigma_i^- = 1$, and σ_i^+ refers to the weight of expected output, σ_i^{z-} refers to the weight of unexpected outputs; θ refers to the radial parameters, β refers to the output radial improvement parameters, ε refers to the combination of radial and non radial parameters.

The GML index includes production inputs and outputs in a production frontier that covers sample data from all measurement years, achieving transferability and cyclic accumulation, making the results more reliable. Among them, the global production possibility set $P^G(x)$ the specific expression is:

$$P^G(x) = P^1(x^1) \cup P^2(x^2) \cup P^3(x^3) \cdots P^t(x^t) \quad (5)$$

The specific expression for GML index is:

$$GML_t^{t+1} = \frac{1+\vec{D}_0^G(x^t,y^t,z^t,w^t)}{1+\vec{D}_0^G(x^{t+1},y^{t+1},z^{t+1},w^{t+1})}$$

$$= GTC_t^{t+1} \times GEC_t^{t+1}$$

$$= \frac{1+\vec{D}_0^t(x^t,y^t,z^t,w^t)}{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},z^{t+1},w^{t+1})} \times \left[\frac{1+\vec{D}_0^G(x^t,y^t,z^t,w^t)}{1+\vec{D}_0^G(x^{t+1},y^{t+1},z^{t+1},w^{t+1})} \times \frac{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},z^{t+1},w^{t+1})}{1+\vec{D}_0^t(x^t,y^t,z^t,w^t)}\right] \quad (6)$$

Among them, the GML index refers to the Green Total Factor Productivity (GTFP) index,

$\overrightarrow{D}_0^G(x^t, y^t, z^t, w^t)$ it represents the directional distance function of production activities during period t based on the production frontier of the same whole, $\overrightarrow{D}_0^G(x^{t+1}, y^{t+1}, z^{t+1}, w^{t+1})$ it refers to the directional distance function of production activities during the t+1 period. The GML index can be decomposed into the Green Technology Progress Index (GTC) and the Green Technology Efficiency Index (GEC). Green technology efficiency refers to the efficiency of production management and resource allocation level, manifested as decision-making units taking action on the production boundary line, while green technology progress refers to the level of technological improvement related to pollution emissions and resource waste, manifested as decision-making units moving on the production front.

3.4 Measurement Results of Green Total Factor Productivity in Western Regions

This article uses MaxDEA software, EBM model, and GML index to measure the green total factor productivity of 12 provinces in western China, and analyzes it in two dimensions: time and space.

3.4.1 Time Dimension

From Figure 1 and Table1, it can be seen that the overall green total factor productivity in the western region of China from 2007 to 2020 is divided into a decreasing stage and an increasing stage, with an average value of 1.0375 and a growth rate of 3.75%. During the period from 2007 to 2015, the decline in the green total factor productivity index slowed down and eventually tended to stabilize. The possible reason for this is that with the launch of the Western Development Strategy, the western region focuses on the speed of economic development while neglecting the quality of economic development. At this time, China is still in the period of heavy chemical industry as a whole. After investing a large amount of factors and consuming a large amount of resources, the western region brings high environmental pollution and low benefits, This extensive economic development model has to some extent hindered the development of green total factor productivity. However, in 2013, the National Development and Reform Commission issued the "Outline of the Comprehensive Governance Plan for Key Ecological Areas in the Western Region (2012-2020)", which began to focus on the comprehensive governance of the ecological environment in the western region. This measure promoted the development of green total factor productivity and slowed down the downward trend of the green total factor productivity index. After 2015, the overall green total factor productivity index was greater than 1, and the upward trend has increased, indicating that the green total factor productivity in the western region has been on the rise in these years. The possible reason for this is that the formal proposal of supply side reform has led to the transformation of China's economic structure, which has continuously optimized the ecological system in the western region. While economic development is also focused on protecting the ecological environment, it has promoted the rise of green total factor productivity.

Table 1. Green Total Factor Productivity Index and Its Decomposition Index in the Western Region from 2007 to 2020

particular year	gtfp index	gec index	gtc index
2011	1.068	0.922	1.167
2012	0.984	0.994	0.991
2013	0.990	0.982	1.010
2014	0.989	0.982	1.008
2015	1.004	0.994	1.010
2016	1.225	1.440	0.893
2017	1.180	1.059	1.114
2018	1.135	1.077	1.072
2019	1.099	1.115	0.990

2020	0.779	1.728	0.482
average value	1.038	1.150	0.949

The overall trend of green technology efficiency is consistent with that of green total factor productivity, with an average value of 1.150 and a growth rate of 15.04%; On the whole, the progress of green technology can be divided into three stages: decrease, increase, and decrease, with an average value of 0.949 and a growth rate of -5.07%. The possible reasons for this are: firstly, compared with the eastern and central regions, the western region is relatively backward and cannot retain a large number of talents, which is not conducive to the research and development of advanced technology and the introduction of advanced equipment, making the progress of green technology in the western region slower, Furthermore, it indicates that the western region needs to give more attention to technological research and development; Secondly, with China's continuous emphasis on ecological environment protection and governance, the ecological management system in the western region has become more strict, promoting the development of green technology efficiency in the western region; Thirdly, the current economic development in the western region is still mainly focused on energy consuming industries. Many high consumption and high pollution enterprises are turning to the western region, causing the western region to continuously sacrifice the ecological environment while developing its economy, suppressing the rise of green total factor productivity.

3.4.2 Spatial Dimension

Obtain the average of the gtfp index, gec index, and gtc index from 12 provinces in the western region from 2007 to 2020, and obtain the average green total factor productivity index and its decomposition index for the 12 provinces, as shown in Table2.

Table 2. Green Total Factor Productivity Index and Its Decomposition Index of 12 Provinces in the Western Region

region	gtfp index	gec index	gtc index
Inner Mongolia	1.068	1.128	0.990
Guangxi	1.006	1.164	0.924
Chongqing	1.087	1.237	0.948
Sichuan	1.048	1.171	0.930
Guizhou	1.007	1.150	0.934
Yunnan	1.022	1.166	0.935
Tibet	1.022	1.000	1.022
Shaanxi	1.041	1.195	0.942
Gansu	1.088	1.236	0.928
Qinghai	1.025	1.125	0.941
Ningxia	1.034	1.148	0.942
Xinjiang	1.002	1.083	0.955

From Table 2, it can be seen that the average green total factor productivity index of the 12 provinces in the western region is greater than 1, which reflects the continuous increase in green total factor productivity in the western region from 2007 to 2020, indicating that green total factor productivity has a promoting effect on the economy; The average green technology efficiency of all 12 provinces in the western region, except for Tibet, is greater than 1, indicating that the green technology efficiency of these 11 provinces has been improved to varying degrees. However, the average green technology efficiency of Tibet is 1, which means that the green technology efficiency of Tibet remains basically stable; Except for Tibet, the progress in green technology is less than 1 in all other provinces, which means that only Tibet's green technology progress has been developed during the 14 year period from 2007 to 2020. The above data reflects that the driving force for the improvement of green total factor productivity in the western region mainly comes from the improvement of green technology efficiency, and the effect of green technology efficiency on green total factor productivity is greater than that of green technology progress. The possible reasons for this are: firstly, in order to promote green development in the western region, the government has issued some guiding and encouraging documents. These preferential policies have made the western region focus on improving production management efficiency and better allocating resources, promoting the development of green technology efficiency, and thus promoting the development of green total factor productivity in the western region; Secondly, even with the guidance of many preferential policies, the western region itself lacks high-quality talents, resulting in a lack of innovation and improvement in technologies related to reducing pollution emissions and improving resource utilization, and the inability to develop green technology progress. This means that it may inhibit the development of green total factor productivity in the western region. Thirdly, due to Tibet's unique geographical environment advantages, it has a relatively small ability to accept industrial transfer from the eastern and central regions. Therefore, compared to other provinces in the western region, the Tibet Autonomous Region generates less pollution emissions and resource waste. Under the guidance of government policies, Tibet pays more attention to technological improvement.

4. A Study on the Spatial Spillover Effect of Green Total Factor Productivity in Western Regions

4.1 Model Design

Based on the green total factor productivity results of 12 provinces in the western region measured above, this paper takes green total factor productivity (gtfp) as the explained variable according to the panel data of 12 provinces in the western region from 2007 to 2020, and constructs the model as follows:

$$gtfp_{it} = \alpha_0 + \alpha_1 X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (7)$$

Where i represents the province, t represents the time, $gtfp_{it}$ refers to the dependent variable, X_{it} refers to the control variable, γ_i refers to individual fixed virtual variables, δ_t refers to a time fixed virtual variable, ε_{it} it refers to the random Error term.

In order to analyze the internal relationship between various variables and green total factor productivity from a spatial perspective, a spatial econometric model is constructed for empirical analysis. The specific expression is:

$$gtfp_{it} = \beta_0 + \beta_j X_{it} + \sigma_0 W gtfp_{it} + \sigma_l W X_{it} + \gamma_i + \delta_t + \omega_{it}$$
$$\omega_{it} = \rho W \varphi_{it} + \varepsilon_{it} \quad (8)$$

W refers to the spatial weight matrix, $Wgtfp_{it}$ it refers to the lagging term of green total factor productivity, WX_{it} refers to the spatial lag term of the control variable, β_j refers to the regression coefficient of the control variable, σ_0, σ_l refers to the regression coefficients of green total factor productivity and the spatial lag term of the control variable, respectively.

4.2 Indicator Selection

Industrial structure (is): High consumption and high pollution industries can promote economic development, but at the cost of the ecological environment, it is not conducive to green development. The secondary industry itself has a significantly higher demand for resources and damage to the environment than the primary and tertiary industries. This article selects the ratio of the secondary industry to GDP to measure industrial structure.

Environmental regulation (egi): As long as there are two theories related to environmental regulation: the "follow cost theory" and the "Porter hypothesis". The main environmental regulation of "following the cost theory" will increase the pressure on enterprises' environmental protection, forcing them to increase investment in pollution control, reducing funds for technological innovation, inhibiting productive investment, and thus hindering the development of green total factor productivity; The "Porter Hypothesis" suggests that strict environmental regulations make enterprises focus on innovation in environmental protection technology.

Environmental protection technology can reduce pollution emissions, offset some or even all of the cost pressure brought by environmental regulations, and ultimately promote the development of green total factor productivity. This article selects the proportion of investment completed in industrial pollution control in the region to GDP to measure environmental regulation. Due to the small proportion of income, it is converted into a thousand points.

Government behavior (gov): On the one hand, increasing fiscal expenditure can promote the transformation and upgrading of enterprises, provide financial support for technological innovation, and thus promote green technology progress; On the other hand, the increased fiscal expenditure may be used to increase the size of enterprises, neglecting the efficiency of production factor utilization, leading to high investment and low output. This article uses the proportion of fiscal expenditure to GDP to reflect government behavior.

Economic development level (es): On the one hand, economic development can bring progress in productivity and growth in output level; On the other hand, economic development can also lead to resource waste and environmental damage, thereby inhibiting the development of green total factor productivity. This article selects per capita GDP as a measure of economic development level.

Foreign Investment (FDI): On the one hand, an increase in foreign investment is beneficial for attracting foreign capital, achieving high output and low pollution through technological improvements, and promoting green development; On the other hand, foreign-funded enterprises, in order to avoid strict environmental regulations abroad, will transfer some high pollution and high loss production activities, causing pressure on the ecological environment, thereby limiting the development of green total factor productivity. This article uses the ratio of the total investment of foreign-invested enterprises to GDP to measure foreign investment.

Research investment (RD): Increasing R&D investment can promote technological innovation in enterprises, develop green technologies, reduce pollution emissions, improve economic development levels, and ultimately promote the development of green total factor productivity. This article selects local financial science and technology expenditures from various provinces to measure scientific research investment. Due to the large size of the data, it is logarithmically processed.

Table 3. Variables and Their Explanation

	variable	Symbol	Variable Description
Dependent variable	Green Total Factor Productivity	gtfp	EBM-GML calculation
Explanatory variable	industrial structure	is	Value added of the secondary industry/GDP
	Government behavior	gov	Fiscal expenditure/GDP
	Economic development level	es	Per capita GDP
	foreign investment	fdi	Total investment of foreign-invested enterprises/GDP
	Scientific research investment	lnrd	The logarithm of local fiscal science and technology expenditure

4.3 Spatial Correlation Test

Table 4. Moran's I Index of Green Total Factor Productivity in China's Provinces from 2007 to 2020

time	Moran's I index	P-value
2007	0.119	0.044
2008	0.124	0.021
2009	0.115	0.071
2010	0.139	0.030
2011	0.159	0.046
2012	0.163	0.005

2013	0.155	0.047
2014	0.136	0.001
2015	0.173	0.043
2016	0.164	0.051
2017	0.166	0.014
2018	0.187	0.054
2019	0.170	0.005
2020	0.188	0.062

Based on the green total factor productivity results of the western region measured above, this paper uses the geographical metric space weight matrix to carry out an autocorrelation test on the green total factor productivity of the western region from 2007 to 2020, and obtains Table 4.

From Table 4, it can be seen that the Moran index of green total factor productivity in the western region passed the significance test from 2007 to 2020.

4.4 Selection of Spatial Econometric Models

Table 5. Relevant tests of spatial econometric models

test	Statistical value	P-value
LM Spatial error	205.417	0.000
Robust LM Spatial error	172.508	0.000
LM Spatial lag	35.739	0.000
Robust LM Spatial lag	2.831	0.092
Wald Spatial error	15.950	0.007
Wald Spatial lag	17.730	0.003
LR Spatial error	15.060	0.010
LR Spatial lag	16.570	0.005
Hausman	51.560	0.000
LR rtest both ind, df(10)	67.230	0.000
LR lrtest both time, df(10)	20.220	0.027

First, the panel data of the western region from 2007 to 2020 were tested by Lagrange factor (LM), and the SEM model, SLM model and SDM model were selected. If the LM Spatial error is more significant than the LM Spatial lag test, and only the former has passed the significance level test between the two, it can be said that the panel data is more suitable to select the SEM model for estimation, otherwise, SLM model is more suitable. From the test results in Table 5, it can be seen that the P-values of LM Spatial error and LM Spatial lag both passed the 1% significance level test, both of which were 0.0000. At the same time, the P-values of Robust LM Spatial error and Robust LM Spatial lag were both 0.0000, which also passed the 1% significance level test. Therefore, whether choosing SLM model or SEM model is appropriate, in order to better estimate the model, this article chooses SDM model as the more appropriate choice.

After determining the SDM model, the adaptability of the model was also tested through LR and Wald tests. According to the test results in Table 5, the P-value of Wald Spatial error is 0.0070, indicating that the original hypothesis was rejected at a significance level of 1%, that is, the SDM model cannot degenerate into an SEM model; The P-value of Wald Spatial lag is 0.0033, indicating that at a significance level of 1%, it also rejects the original hypothesis that the SDM model cannot degenerate into an SLM model. Therefore, for the research in this article, the SDM model is better.

In addition, it is necessary to choose between a random effects model and a fixed effects model. According to the Hausman test results in Table 5, its P-value is 0.0000, which passes the 1% significance level test. Therefore, this article is more suitable for selecting a fixed effects model for regression analysis.

After determining the fixed effects, it is necessary to select individual fixed effects, time fixed effects, and individual time double fixed effects. According to the LR test of the fixed effects model, this article is more suitable for selecting the double fixed effects model.

4.5 Empirical Analysis of Spatial Durbin Model

This article adopts the time individual double fixed effect spatial Durbin model for regression analysis. According to Table 6, the spatial correlation coefficient is -0.5114, which passes the 1% significance level test, indicating that the green total factor productivity of 12 provinces in the western region has a significant spatial negative effect.

As for the explanatory variable, the coefficient of industrial structure is 0.6847, but it did not pass the significance test. The spatial lag term of industrial structure is positive, indicating that the industrial structure in the western region does not have a significant effect on the green total factor productivity of the province, but can significantly promote the development of green total factor productivity in neighboring provinces. The regression coefficient of foreign investment is 26.1841, which passed the significance level test of 5%. However, its spatial lag term is not significant, indicating that foreign investment only has a significant promoting effect on the green total factor productivity of the province. The regression coefficient of government behavior is significantly negative, but its spatial lag term is not significant. This may be because government intervention has increased fiscal expenditure, but the profit seeking nature of enterprises has led to more investment in scale expansion, ignoring the development of green technology, which is detrimental to the development of green total factor productivity. The regression coefficient of economic development level is significantly negative, and its spatial lag term is also significantly negative, indicating that economic development brings more waste of resources and pollution emissions, which has a negative impact on the green total factor productivity of this province and neighboring provinces. The scientific research investment and its spatial lag terms did not pass the significance test.

Table 6. Regression Results of SDM Double Fixed Effect Model

variable	SDM model
is	0.685
	(0.452)
fdi	26.184**
	(11.888)
gov	-0.514***
	(0.200)
es	-0.069**
	(0.029)
lnrd	0.014
	(0.061)
W*is	8.906***
	(2.770)
W*fdi	36.195
	(62.261)
W*gov	-0.702
	(0.946)
W*es	-0.584***
	(0.191)
W*lnrd	-0.052
	(0.267)
Log-likelihood	157.806
R-squared	0.151
rho	-0.511**
Observations	168

Note: * * *, * *, * respectively indicate significant at the 1%, 5%, and 10% levels; The values in parentheses are standard errors.

4.6 Analysis on the Spillover Effect of Green Total Factor Productivity in Western Regions

This article analyzes the direct effects, spillover effects, and total effects of each explanatory variable on the region through the SDM model. The direct effects indicate the direct impact of the explanatory variable on the dependent variable in the province; The spillover effect refers to the spillover effect of explanatory variables on neighboring provinces of a province, also known as indirect effects; The total effect is the sum of direct and indirect effects. The specific regression results are shown in Table 7.

Table 7. Results and decomposition of the double fixed effects model

variable	Direct effect	overflow effect	Total effect
is	0.269	6.416***	6.685***
	(0.420)	(2.222)	(2.472)
fdi	24.541**	14.984	39.526
	(11.357)	(45.547)	(46.132)
gov	-0.492**	-0.247	-0.739
	(0.198)	(0.651)	(0.674)
es	-0.041	-0.405***	-0.446
	(0.030)	(0.151)	(0.152)

lnrd	0.025	-0.029	-0.005***
	(0.054)	(0.171)	(0.197)

Note: * * *, * *, * respectively indicate significant at the 1%, 5%, and 10% levels; The values in parentheses are standard errors.

The direct effect of industrial structure is not significant, while the spillover effect and total effect are significantly positive, indicating that industrial structure has a significant promoting effect on the development of green total factor productivity in the western region as a whole, and has a significant positive impact on the green total factor productivity of neighboring provinces. Foreign investment only shows a significant positive effect in the direct effect, while the spillover effect and total effect, although positive, are not significant, indicating that foreign investment only has a significant promoting effect on the development of green total factor productivity in the province. Government behavior is not significant in terms of spillover effects and overall effects, but is significantly negative in terms of direct effects, indicating that government behavior significantly inhibits the development of green total factor productivity in this province. The level of economic development has only passed the significance level test in terms of spillover effects, and is a negative effect, indicating that the level of economic development will have a negative impact on the development of green total factor productivity in neighboring areas of this province. The total effect of scientific research investment is only significantly negative, indicating that the increase in scientific research investment has an overall inhibitory effect on green total factor productivity in the western region.

5. Summary and Suggestions

This paper selects the panel data of 12 provinces in the western region from 2007 to 2020 to calculate the green total factor productivity in the western region, selects the control variables such as industrial structure, government behavior, economic development level, foreign investment and scientific research investment, and uses the spatial Durbin model to conduct empirical analysis. The following conclusions are obtained: First, the green total factor productivity in the western region is divided into two stages: the declining stage and the rising stage; Secondly, the green total factor productivity of 12 provinces in the western region has a promoting effect on the economy, and its improvement is mainly driven by the improvement of green technology efficiency; Thirdly, there is a significant spatial negative correlation between green total factor productivity in the western region. Foreign investment has a promoting effect on the development of green total factor productivity in the western region, while government behavior and economic development level have a restraining effect; Fourth, the industrial structure has a significant positive spillover effect on neighboring provinces, while the level of economic development has a negative spillover effect.

Based on the empirical results of this article, in order to promote the better development of green total factor productivity in the western region, the following suggestions are proposed:

Firstly, improve the level of green technology. The western region should pay attention to the introduction of green technology, increase investment in technologies related to reducing pollution emissions and improving resource utilization, and choose to collaborate with some universities for talent training, in order to introduce high-quality talents and provide conditions for the development of green technology progress.

Secondly, promote the upgrading of industrial structure. The western region should combine its development advantages and choose to accept industrial transfers from other regions to avoid environmental problems. In industrial development, it is also necessary to strictly comply with relevant environmental requirements, encourage enterprise technological innovation, and promote the development of green total factor productivity in the western region.

Thirdly, pay attention to the quality of foreign investment introduction. The western region should make necessary choices when facing foreign investment projects, reject some high pollution and high loss projects, eliminate pollution problems from the root, require the imported foreign investment production process to meet environmental protection requirements, strive to achieve the goal of low pollution and low loss, and promote the development of green total factor productivity in the western region.

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References

Charnes A, Cooper W. W., Rhodes E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444.

Dension E. (1967). Why growth rates differ: post-war experience in nine western countries. *Washington Brookings Institution*, (2), 49-57.

Feng Chao, Wang Miao. (2019). Journey for green development transformation of China's metal industry: A spatial econometric analysis. *Journal of Cleaner Production*, (225), 1105-1117.

Li Kaifeng, Li Zihao. (2022). Measurement of Green Total Factor Productivity in the Yellow River Basin. *Statistics and Decision*, (04), 98-101.

Li Rao. (2021). Research on the Measurement and Influencing Factors of Green Total Factor Productivity in Liaoning Province. Liaoning University.

Solow, R. (1957). Technical change and aggregate production function. *American Economic Review, 39*(3), 312-320.

Sun Jinling, Zhu Peiyu. (2019). Evaluation of green economic efficiency and analysis of influencing factors in key provinces along the "the Belt and Road" based on SBM Malmquist Tobit. *Science and Technology Management Research, 39*(12), 230-237.

Wang Yun, Sun Xiaohua, Guo Xu. (2019). Environmental regulation and green productivity growth: empirical evidence on the Porter Hypothesis from OECD industrial sectors. *Energy Policy*, (132), 611-619.

Wu Jing, Xiao Hongbo, Chen Bing. (2022). Research on the Impact of Digital Economy on Green Total Factor Productivity. *Finance and Economics*, (01), 55-63.

Yang Wenpu, Zeng Huifeng. (2022). Evaluation of the Effect of Digital Economy on Improving Total Factor Productivity. *Technology Economy, 41*(09), 1-9.

Zhang Aoxiang, Deng Rongrong. (2022). The impact and spatial spillover effect of digital inclusive finance on agricultural green total factor productivity. *Wuhan Finance*, (01), 65-74

Zhang Hao, Zhang Jianhua. (2016). Growth momentum and spillover effect of regional total factor productivity: an empirical study based on China's municipal panel data. *Technical Economy, 35*(09), 84-91.

Zhao Dan. (2021). Research on the Spillover Effect of Green Total Factor Productivity Growth in Provincial Areas of China. Chongqing University of Technology.

Zhou Yongfeng. (2018). Measurement of Changes in Total Factor Productivity in China: 1991-2015. *Financial Theory and Practice, 464*(3), 18-22.