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Agricultural Green Total Factor Productivity under the Distortion of the Factor Market in China

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Abstract: The scientific and reasonable measurement of agricultural green total factor productivity is helpful to grasp the direction of rural-factor-market reform. This study constructs a Malmquist productivity index based on a non-radial and non-angular SBM directional distance function. This study calculates the agricultural green total factor productivity of 28 provinces (cities and autonomous regions) in China from 1997 to 2020 by considering unexpected outputs such as carbon emissions and agricultural non-point-source pollution. Finally, this study uses the spatial Dobbin model to explore the spatial impact of agricultural green total factor productivity under the distortion of the factor market. The results show that the agricultural green total factor productivity, considering the unexpected outputs, is more in line with the level of high-quality green development in China's agriculture. Regardless of whether the unexpected output is included, the increase in China's agricultural total factor productivity is primarily due to progress in agricultural technology, and the double boost is little in agricultural technology progress and technical efficiency. Agricultural green total factor productivity shows an increasing trend, but the growth rate is slow, and differences in different regions are significant. Factor market distortion negatively impacts agricultural green total factor productivity, and other factors improve the agricultural total green factor productivity. However, factor market distortion has a particular spatial spillover effect, which hinders the synchronous growth of agricultural green total factor productivity in different regions. Therefore, the government should promote the reform of the agricultural mode of production and agricultural green production, eliminate the blocking effect of factor market distortion on the improvement in agricultural green total factor productivity, narrow the regional gap of agricultural total factor productivity, and establish a policy system for high-quality green development of modern agriculture.

Keywords: agriculture; green total factor productivity; factor market distortion; spatial effect

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1. Introduction

Green growth in agriculture must promote the implementation of ecological development, maintain ecological enrichment and benefit the people. The sources of agricultural productivity growth must be identified, and the potential of agricultural production must be tapped to implement the rural revitalisation strategy and promote the green and high-quality development of modern agriculture. Maintaining green water and mountains is an inevitable requirement for the high-quality development of modern agriculture, including vigorously developing a green ecological agricultural industry through integrating the agricultural industry. Only through the value transformation of agricultural ecological products can ecological resources, such as green water and green mountains, be transformed by agricultural production and management into economic benefits. The green development of modern agriculture is to protect and improve the ecological environment, develop green industries in an all-round way and transform the advantages of the ecological environment into advantages of an ecological economy, such as with ecological agriculture and ecological tourism. All these contribute to transforming green water and green mountains into golden and silver mountains to realise the green and high-quality development of agriculture and rural areas.

China's factor marketisation reform is slower than the commodity market, and the differences are significant. The process of factor marketisation in the developed eastern provinces is faster than in the central and western provinces. The differences in market allocation and the market-oriented transaction of various resource elements in different regions affect the agricultural production and management structure and output efficiency to a certain extent. The value of green ecological resources is often forgotten. The input and output of agricultural production under the distortion of factor market allocation will be inefficient. The distortion of the factor market will restrict agricultural competitiveness and hinder the healthy development of the agricultural and rural economies. Thus, we should actively promote the process of the market-oriented reform of factors and calculate the value of green ecological resources in agricultural production. We can fundamentally improve the production efficiency of green agriculture only if measures are taken to reduce the distortion of the factor market, which involves continuing to support the healthy and sustainable growth of farmers' income.

The concept of 'two mountains' explains the relationship between ecological protection and productivity. The initial proposal was that protecting ecological resources equates to developing productivity [1]. In addition to traditional resource elements, such as capital and labour, ecological resources have become an important guarantee for high-quality and green economic development. The potential and benefits of economic development can be increased through the value transformation of ecological resources [2]. Classical economic theory reveals that economic growth originates from the input quantity and allocation efficiency of factor resources. Many kinds of factor resources in economic development are available. Existing research mainly involves the analysis of traditional input factors such as capital and labour [3]. The quantitative analysis of the economic growth efficiency of multiple factor inputs mainly adopts the total factor productivity method to measure the input–output efficiency of factors and the efficiency of different factor combinations. However, the important role of environmental factors, such as ecological resources in economic growth, is often neglected. Green total factor productivity includes environmental factors, such as ecological resources, to investigate the impact of production factors, including ecological factors, on economic growth efficiency [4].

In the current literature, the measurement methods of agricultural green total factor productivity mainly adopt two kinds of methods: data envelopment analysis combined with the Malmquist productivity index to analyse productivity and the stochastic frontier analysis method considering the random disturbance term. Using these two methods, domestic researchers have conducted much research on agricultural green total factor productivity in China and various regions, decomposed green total factor productivity, analysed the space–time characteristics of green total factor productivity and its decomposition items, and discovered the source of growth. In some studies, when using stochastic frontier analysis, we take environmental pollution as the input variable if we want to consider the unexpected output. Agricultural total factor productivity measures the input–output allocation structure and efficiency of various factors in agricultural growth. Existing studies have focused on the reasons for the changes in China's agricultural total factor productivity and explored the changes in China's agricultural total factor productivity from the perspectives of agricultural-production input factor combination, factor quality and agricultural-policy adjustment [5–8]. The development of green ecological agriculture is a key area of agricultural supply side structural reform. The green development of agriculture enriches the essential connotation of the concept of 'two mountains' and is also the essential requirement of the transformation of 'two mountains'. Over the years, China's extensive agricultural growth has been unsustainable, and agricultural production is facing severe resource and environmental-degradation problems. For many years, the No. 1 central document of the central government has put the green development of ecological agriculture in the first place. The concept of 'green water and green mountains are golden mountains and silver mountains' has been deeply rooted in people's hearts. Green agriculture total factor productivity has been gradually studied [9,10]. Many studies have integrated ecological-resource elements into measuring total factor productivity. The results show that the calculation results of total factor productivity considering environmental pollution or agricultural carbon emissions are closer to the reality of China's agricultural development [11,12]. Significant differences have been observed in the basic conditions, resource factor endowments and factor market development of agricultural development in different regions of China, giving the agricultural green total factor productivity in different regions large spatial differences. Total factor productivity in different regions may result in the spatial heterogeneity of agricultural-production structure and production and operation benefits, affecting the coordinated and stable development of agricultural production and operation in different regions [13–15]. Existing studies have concluded that agricultural technology progress is the main factor of agricultural green total factor productivity growth, and its spatial and regional differences will exist for a long time, but different studies have different regional differences [16]. Furthermore, different methods have been adopted to deal with different input–output values of agricultural green total factor productivity. Some studies are treated as input factor variables, whereas others are treated as unexpected output variables. Some studies dealing with environmental pollution factors only involve agricultural non-point-source pollution, resulting in a poor comparability of research results [17,18]. The cross-impact of different factor inputs in agricultural production will worsen the environment to a certain extent [19,20].

While China's agriculture is developing rapidly, it still faces great challenges. For example, China's agricultural development is extensive, the utilisation efficiency of agricultural resources is low, and the unexpected output is too high and faces increasingly tight resource constraints. Under such requirements, taking the traditional agricultural total factor productivity as an indicator to measure agricultural development is no longer feasible. Considering the agricultural green total factor productivity after environmental pollution is necessary. The existing studies on the total factor productivity measure discuss the output efficiency of optimal allocation of multiple factors under a perfect competitive factor market [21]. Existing studies have focused on the impact of factor market distortion on the total factor productivity of different industries and have concluded that eliminating factor market distortion can effectively improve total factor productivity [22,23]. However, the process of factor marketisation in China is relatively slow. The distortion of the factor market in different regions makes the input–output effect of the combination of input factors in agricultural production and management in different regions uncertain [24,25]. Neglecting the mismatch of factor resources will affect the efficiency of agricultural production and affect the effect measurement of agricultural total factor productivity of various factor inputs and agricultural technology progress and the optimisation and adjustment of agricultural-related policies [26,27]. Differences in economic development and factor endowments in different regions will lead to differences in agricultural production-efficiency. Part of the research involves the regional difference analysis of agricultural green total factor production [28,29].

To sum up, the existing literature on agricultural total factor productivity is not comprehensive and specific. It ignores the selection of unexpected output involved in measuring green total factor productivity. It also ignores the spatial impact of factor market price distortion on agricultural green total factor productivity. Given the complexity of the input–output relationship of China's agricultural production, the constraints of different input factors and the negative impact of unexpected output on the environment are urgently and comprehensively investigated. It is of great practical significance to bring various input factors and unexpected outputs under the distortion of the factor market into a research framework to solve the high-quality green development of China's agriculture. Therefore, this study comprehensively selects various input–output factors to calculate agricultural green total factor productivity in different regions and discusses the spatial impact of factor market distortion on agricultural green total factor productivity in different regions and its spillover effect based on the spatial econometric model to provide more effective suggestions for the regional-difference policy adjustment of agricultural green and high-quality development.

2. Materials and Methods

2.1. Calculation Method of Agricultural Green Total Factor Productivity

The most important point of measuring agricultural green total factor productivity is to include the unexpected output in the measurement system. Data envelopment analysis is a commonly used method to calculate agricultural green total factor productivity when considering environmental and resource factors. The Malmquist productivity index based on the non-radial and non-angular SBM directional distance function can solve the negative deviation impact of dimensional difference and angle selection on efficiency evaluation. The specific form is as follows:

$$\mathrm{Min}\rho = \frac{1 - \frac{1}{\mathrm{N}}\sum\limits_{\mathrm{n}=1}^{\mathrm{N}} \frac{\mathrm{s}_\mathrm{n}^\mathrm{x}}{\mathrm{x}_{\mathrm{n}0}}}{1 + \frac{1}{\mathrm{M}+\mathrm{I}}\left(\sum\limits_{\mathrm{m}=1}^{\mathrm{M}} \frac{\mathrm{s}_\mathrm{m}^\mathrm{y}}{\mathrm{y}_{\mathrm{m}0}} + \sum\limits_{\mathrm{i}=1}^{\mathrm{I}} \frac{\mathrm{s}_\mathrm{i}^\mathrm{u}}{\mathrm{u}_{\mathrm{i}0}}\right)} \quad (1)$$

$$\text{s.t.} \sum_{k=1}^{K} z_k x_{nk} + s_n^x = x_{n0}, n = 1, 2, \ldots, N; \quad (2)$$

$$\sum_{k=1}^{K} z_k y_{mk} - s_m^y = y_{m0}, m = 1, 2, \ldots, M; \quad (3)$$

$$\sum_{k=1}^{K} z_k u_{mk} + s_i^u = u_{i0}, i = 1, 2, \ldots, I; \quad (4)$$

$$\sum_{k=1}^{K} z_k = u_{i0}, 1; \quad (5)$$

$$z_k \geq 0; s_n^x \geq 0; s_m^y \geq 0; s_i^u \geq 0 \quad (6)$$

In calculating agricultural green total factor productivity, the choice of indicators will directly affect the scientific rationality of the calculation results. The measured indicators are divided into two parts: output indicators and input–output indicators. If the output indicators do not include unexpected output, the traditional total factor productivity is measured; otherwise, it is the green total factor productivity considering environmental pollution. ρ represents the ecological efficiency value of agricultural production, $0 \leq \rho \leq 1$. When ρ is 1, agricultural production has complete efficiency, input and output can match completely, and no problems such as excess factor input and insufficient expected output are encountered. When ρ is less than 1, efficiency loss occurs in agricultural production, and input–output imbalance leads to low production efficiency. Input–output in agricultural production must be optimised to enhance ecological efficiency. $\mathrm{S}_\mathrm{n}^\mathrm{x}$ and S_i^u indicate the excess of various factor resource inputs and unexpected outputs, such as agricultural non-point-source pollution and carbon emissions, which can indicate the ecological environment problems between inputs and outputs. S_m^y indicates that the expected output, such as the added value of agricultural production, is insufficient. By incorporating the relaxation of input variables, expected output variables and unexpected output variables, the non-efficiency problem caused by input–output relaxation is solved. The study calculated the agricultural green total factor productivity of 28 provinces (cities and autonomous regions) in China from 1997 to 2020 based on the ecological efficiency value, decomposed it into the technical progress index and technical efficiency change index and analysed it according to the east, middle and west regions.

2.2. Space Panel Measurement Model

The existing literature has conducted extensive research on the influencing factors of agricultural green total factor productivity from multiple perspectives, including agricultural financial subsidies, agricultural structure, factor input structure, urbanisation, financial inclusion, foreign direct investment, scientific research investment, human capital, labour transfer and rural infrastructure. Furthermore, many other factors and the relationship between agricultural green total factor productivity exist. Under the distortion of the factor market, the input–output efficiency of agricultural production is difficult to reach the Pareto optimal state. The mismatch of factor resources may lead to the inefficiency of agricultural-production activities and ultimately affect the high-quality green development of agricultural production. This study uses the spatial panel data of 28 provinces (cities and autonomous regions) from 1997 to 2020 to explore the impact of factor market distortions on agricultural green total factor productivity considering unexpected output and to analyse the impact of factor market distortions, such as capital, labour and land on agricultural green total factor productivity scientifically. The spatial Dobbin model is established. Agricultural green total factor productivity is taken as the explanatory variable; factor market distortion is taken as the key explanatory variable; and six variables are taken as control variables, i.e., rural human capital, rural financial development scale, agricultural product trade openness, agricultural scale management level, regional industrialisation level and agricultural policy adjustment.

$$Y_{it} = \alpha_{it} I_{it} + \rho W Y_{it} + \beta_{it} X_{it} + \theta W X_{it} + \varepsilon_{it} \tag{7}$$

Y_{it} is agricultural green total factor productivity, X_{it} is an independent variable matrix of order (factor market distortion value and six control variables), and W is an order spatial weight matrix. The spatial weight reflects the spatial correlation between economic variables. The impact of regional correlation is smaller when the distance is far away. This study uses the geographical distance between provincial capitals to construct the spatial weight matrix. The exogenous variables whose geographical distance between provincial capitals is fixed for a long time and is not affected by social and economic activities can avoid the endogenous problem of the spatial econometric model to a certain extent. WY and WX represent the spatial effects of the explained variable and the explanatory variable, respectively. WY_{it} is the spatial autoregressive term of the dependent variable. ρ is the spatial autoregressive coefficient. θ is the spatial autoregressive coefficient. ε_{it} is the random error term vector. The reciprocal of the spatial distance between the provincial capitals will be used for verification to test the robustness of the spatial Doberman model. Finally, the spatial effect is decomposed into direct, indirect and total effects based on the partial differential method.

2.3. Index Selection and Data Source

2.3.1. Input Output Indicators

Under the distortion of the capital market, labour market, land market and other factor markets, the input of agricultural-production factors deviates from the optimal allocation state. Changing the agricultural-production status of high consumption, low output and high pollution in China's agriculture is urgent. The long-standing imbalance between expected and unexpected output has plagued agriculture's green and high-quality development. This study includes the input indicators of capital, labour, land and water. This study also involves agricultural added value, agricultural non-point-source pollution and carbon emissions in the output indicators as expected and unexpected output, respectively, to measure the agricultural green total factor productivity comprehensively. The capital investment is measured by the total power of agricultural machinery, the use of pesticides and the use of chemical fertilisers. The labour input is measured by the agricultural population, the land input is measured by the sowing area, and the water input is measured by the agricultural water consumption. The expected output is measured by the agricultural added value, excluding intermediate consumption, and reduced by the agricultural product price index in 1997. Based on the extensive production practice of high pollution and high energy consumption in China's agricultural development, the unexpected output is measured by agricultural non-point-source pollution and carbon emissions. Neglecting environmental damage under the distortion of the factor market will mislead the adjustment of agricultural high-quality development policy to a certain extent. The measurement of agricultural green total factor productivity must consider the impact of various environmental resource constraints in agricultural production. Agricultural non-point-source pollution mainly comes from farmland chemical fertilisers, pesticides, aquaculture, livestock and poultry breeding. It is estimated according to the quantity and coefficient of non-point-source pollution in agricultural production. Carbon emissions mainly come from direct and indirect consumption of pesticides, chemical fertilisers, agricultural films and fuel oil, which are estimated according to existing literature methods.

2.3.2. Influencing Factors

The core explanatory variable of agricultural green total factor productivity is factor market distortion, measured by the average value of capital, labour and land market distortions. The factor market distortion of China's capital market and labour market is estimated by the C-D production function, and the factor market distortion of land is estimated by the ratio of residential land price to industrial land price. Rural human capital is estimated based on the average level of education in rural areas. According to the education status of rural residents' family labour force in the region, based on 0 × illiterate and semi-illiterate + 6 × primary level + 9 × junior high school level + 12 × high school level + 12 × technical secondary school level + 15.5 × college degree or above, the situation of rural human capital is calculated in each region. The scale of rural financial development is expressed by the proportion of the sum of rural deposits and loans to the GDP of the primary industry. The openness of agricultural trade is measured by the ratio of the total value of import and export commodities converted into RMB according to the current exchange rate to the regional GDP. The scale management level of agriculture is expressed by the ratio of the total power of agricultural machinery to the area of regional cultivated land. The level of regional industrialisation is measured by the proportion of the secondary industry's added value in the regional GDP. The adjustment of agriculture-related policies is expressed by the ratio of government agriculture-related fiscal expenditure to regional GDP. Restricted by the availability of some variable data, this study selects the data of 28 provinces (cities and autonomous regions) from 1997 to 2020 for analysis. The research data are from *China Statistical Yearbook (1998–2021)*, *China Rural Statistical Yearbook (1998–2011)*, China 60-year statistical data collection and *China Environmental Statistical Yearbook (1998–2021)*.

3. Results

3.1. Analysis on Measurement Results of Agricultural Green Total Factor Productivity

3.1.1. Comparison between Agricultural Total Factor Productivity and Green Total Factor Productivity

In this study, maxdea6.0 software was used to calculate the agricultural green total factor productivity considering unexpected output and the agricultural total factor productivity without considering unexpected output in the 28 provinces (cities and autonomous regions) of China from 1997 to 2020. A series of preferential agricultural policies have effectively promoted agricultural-production efficiency, as shown in Table 1. In general, the agricultural green total factor productivity is less than the agricultural total factor productivity. The agricultural green total factor productivity considering the unexpected output, such as carbon emissions and agricultural non-point-source pollution, can better measure the actual agricultural production efficiency. After the agricultural-production mode reform in the past year, the agricultural green production mode has not been completely transformed. China's extensive and rapid agricultural growth has been based on high pollution and high consumption for a long time. It cannot maintain the long-term stability of agriculture, which is contrary to the concept of green development of an ecological economy transformed by 'two mountains'. The transformation and development of green and high-quality agriculture are imminent, and the need for changing the mode of agricultural production is urgent. From the time series perspective, China's agricultural total factor productivity has generally increased, but fluctuations are also observed within a certain range. On the whole, the growth of agricultural green total factor productivity is lower than that of agricultural total factor productivity. The results show that the level of total factor productivity is overestimated to a certain extent without considering environmental pollution and other factors in agricultural production, which easily causes policy evaluation deviation and further distorts the input–output relationship of the agricultural output. The history of China's agricultural development shows that the agricultural production and operation mode that has been constantly optimised and adjusted has adapted to the requirements of the development of ecological agriculture with green waters and green mountains. The growth of agricultural green total factor productivity reflects the acceleration of the transformation and upgrading of China's agricultural green production under the concept of 'two mountains'. This growth has changed the extensive agricultural-production mode at the expense of ecological resources and the environment. The ecological advantages of the vast rural areas are transformed into farmers' golden mountains and silver mountains, the agricultural-production mode is made more reasonable, and the recyclable ecological transformation of agricultural resources and the green and high-quality development of agriculture are realised.

Table 1. Measurement results of China's agricultural green total factor productivity from 1997 to 2020.

Year	Total Factor Productivity	Green Total Factor Productivity	Year	Total Factor Productivity	Green Total Factor Productivity
1997	0.963	0.932	2009	1.008	0.977
1998	0.972	0.942	2010	1.020	0.988
1999	0.963	0.933	2011	1.030	0.997
2000	0.945	0.914	2012	0.981	0.950
2001	0.954	0.923	2013	1.039	1.006
2002	0.972	0.942	2014	1.058	1.025
2003	0.926	0.897	2015	1.068	1.034
2004	0.935	0.906	2016	1.009	0.978
2005	0.991	0.959	2017	1.014	0.993
2006	1.001	0.968	2018	1.029	0.997
2007	0.981	0.951	2019	1.022	1.004
2008	1.000	0.968	2020	1.142	1.075

3.1.2. Decomposition of Agricultural Green Total Factor Productivity

This study measures the agricultural green total factor productivity index and its decomposition. It compares the index with the total factor productivity without considering agricultural carbon emissions, non-point-source pollution and other unexpected outputs, as shown in Table 2. The growth of agricultural green total factor productivity in China mainly depends on the contribution of agricultural green technology progress. Most of its numerical results are greater than 1, effectively promoting agricultural green total factor productivity growth. The efficiency of agricultural green technology is less than 1 in all provinces except a few provinces, which indicates that the efficiency of agricultural green technology has restrained the growth of agricultural green total factor productivity to a certain extent. Comparing the total factor productivity without considering agricultural carbon emissions, non-point-source pollution and other unexpected outputs, the two total factor productivity showed an upward trend. The results show that the pure technical efficiency was less than 1, and the improvement in technical progress was significantly greater than the change in technical efficiency. The effects of technical progress and technical efficiency on agricultural total factor productivity were just the opposite, resulting in the slow growth of agricultural total factor productivity. Agricultural green total factor productivity and its scale and technological progress efficiency generally fall behind the situation that does not include agricultural carbon emissions, non-point-source pollution and other unexpected outputs. Thus, agricultural green production under the concept of low-carbon and economic development in the period of China's agricultural green transformation has enhanced the awareness of agricultural resources and ecological environment protection, and agricultural green total factor productivity and agricultural green technological progress have maintained synchronous growth. Therefore, the growth of China's agricultural green total factor productivity mainly comes from the progress of agricultural green technology.

Table 2. Measurement results of agricultural green total factor productivity in 28 provinces (cities, autonomous regions).

Province	Consider Unexpected Outputs Such as Agricultural Carbon Emissions and Non-Point-Source Pollution			Do Not Consider Unexpected Output		
	Green Total Factor Productivity	Technical Efficiency	Technical Progress	Total Factor Productivity	Technical Efficiency	Technical Progress
Anhui	0.968	0.656	0.924	1.019	0.690	0.972
Beijing	1.029	0.677	1.045	1.083	0.712	1.100
Fujian	1.016	0.756	1.050	1.069	0.795	1.106
Gansu	1.006	0.772	1.056	1.059	0.812	1.112
Guangdong	0.979	0.732	1.046	1.031	0.770	1.101
Guangxi	1.009	0.750	1.049	1.062	0.789	1.105
Guizhou	0.931	0.738	0.947	0.980	0.777	0.996
Hainan	1.003	0.752	1.042	1.056	0.791	1.096
Hebei	0.963	0.780	1.118	1.014	0.822	1.177
Henan	1.031	0.771	1.044	1.085	0.811	1.098
Heilongjiang	1.020	0.943	1.047	1.074	0.993	1.102
Hubei	1.012	0.752	1.049	1.065	0.791	1.105
Hunan	1.036	0.771	1.049	1.091	0.811	1.104
Jilin	0.998	0.739	1.053	1.051	0.779	1.109
Jiangsu	1.144	0.949	1.046	1.205	0.999	1.101
Jiangxi	0.995	0.764	1.027	1.047	0.804	1.081
Liaoning	0.947	0.703	1.050	0.996	0.739	1.106
Inner Mongolia	0.924	0.752	0.963	0.973	0.791	1.014
Ningxia	0.915	0.760	0.944	0.963	0.801	0.994
Qinghai	0.913	0.754	0.925	0.961	0.793	0.974
Shandong	0.985	1.029	1.040	1.037	1.083	1.094
Shanxi	0.979	0.723	1.059	1.031	0.761	1.115
Shaanxi	0.943	0.765	0.927	0.993	0.805	0.976
Shanghai	1.029	0.761	1.054	1.083	0.802	1.110
Sichuan	0.977	0.723	0.965	1.029	0.761	1.016
Tianjin	1.031	0.772	1.043	1.085	0.812	1.097
Yunnan	1.004	0.743	1.028	1.057	0.782	1.082
Zhejiang	1.044	1.137	1.057	1.098	1.196	1.113
Eastern provinces	1.016	0.823	1.054	1.151	0.906	1.185
Central provinces	1.005	0.765	1.031	1.098	0.865	1.131
Western Provinces	0.958	0.751	0.978	0.942	0.742	0.970
whole country	0.994	0.782	1.023	1.046	0.836	1.080

Note: the sample of this study is 28 provinces (cities, autonomous regions). According to the division standard of eastern, central and western provinces of the National Bureau of Statistics, the eastern provinces include Beijing, Tianjin, Hebei, Liaoning, Jiangsu, Shanghai, Zhejiang, Guangdong, Shandong, Hainan and Fujian; the central provinces include Anhui, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi and Shanxi; and the western provinces include Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Yunnan and Gansu.

3.1.3. Regional Difference Analysis of Agricultural Total Factor Productivity

A significant regional gap is observed in China's agricultural green total factor production, showing a gradient-decreasing difference between the east, the middle and the west, as shown in Table 2. The average value of agricultural green total factor productivity in the eastern provinces is the highest, followed by the central provinces. The western provinces are the lowest. The values of the eastern and central provinces are higher than the national level, and the regional gap is obvious. Compared with the total factor productivity without considering the unexpected output, such as agricultural carbon emissions and non-point-source pollution, the agricultural total factor productivity in the east, middle and west regions is greater than the agricultural green total factor productivity. Therefore, considering the unexpected output, the agricultural green total factor productivity can better reflect the current reality of China's agricultural development. The decomposition results of agricultural total factor productivity in the three regions of the east, the middle and the west show that technological progress is the main source of promoting its growth. The technological progress of agricultural green technology considering unexpected output is less than that ignoring agricultural carbon emissions and non-point-source pollution. Overall, it is the factor to promote the improvement in total factor productivity. Agricultural technical efficiency has hindered the growth of total factor productivity in the three regions of the east, middle and west. Therefore, the agricultural-production efficiency in the three regions of the east, middle and west mainly depends on the progress of agricultural technology. Its value will be falsely increased without considering agricultural carbon emissions, non-point-source pollution and other factors. Table 2 shows that the agricultural technological progress of the sample provinces is the key factor in improving the agricultural-production efficiency. Only a few provinces, such as Zhejiang and Shandong, jointly promote the growth of agricultural total factor productivity. The agricultural technological efficiency still hinders the improvement in agricultural-production efficiency in the three regions. Therefore, accelerating the green transformation of agricultural-production mode under the guidance of the 'two mountains' concept is necessary to realise the two-wheel-driving effect of agricultural total factor productivity growth and the transformation from agricultural ecological resource advantage to agricultural ecological economic advantage.

3.2. Effect Decomposition of Agricultural Green Total Factor Productivity under Factor Market Distortion

3.2.1. Spatial Impact of Agricultural Green Total Factor Productivity in Different Regions under Factor Market Distortion

Considering spatial correlation, this study uses the Moran index to reveal the spatial correlation degree of green total factor productivity in 28 provinces (cities and autonomous regions). The global Moran index analysis results are shown in Table 3. The Moran index values of agricultural green total factor productivity in Table 3 are all greater than 0 and pass the test at the significance level of 1%. Therefore, China's agricultural green total factor productivity is significantly spatially correlated, with strong spatial dependence. It can be used to conduct an empirical analysis of spatial effects using spatial econometric models.

Table 3. Moran index of agricultural green total factor productivity in 28 provinces (cities, autonomous regions).

Year	MoranI	MoranI Statistical Value	*p* Value	Year	MoranI	MoranI Statistical Value	*p* Value
1997	0.265	13.929	0.008	2009	0.497	20.188	0.002
1998	0.224	16.986	0.001	2010	0.473	24.619	0.001
1999	0.419	22.144	0.001	2011	0.399	17.794	0.001
2000	0.398	15.321	0.003	2012	0.272	22.206	0.001
2001	0.335	18.685	0.000	2013	0.230	17.771	0.003
2002	0.629	25.298	0.000	2014	0.431	13.057	0.000
2003	0.597	16.855	0.001	2015	0.410	24.427	0.002
2004	0.503	20.553	0.004	2016	0.398	29.789	0.000
2005	0.346	28.769	0.001	2017	0.378	18.087	0.000
2006	0.291	18.540	0.004	2018	0.319	26.870	0.001
2007	0.545	22.609	0.001	2019	0.404	18.764	0.000
2008	0.518	13.777	0.001	2020	0.390	21.941	0.000

The regression results of the spatial Dobbin model in Table 4 show that the spatial term coefficients of the three regions in the east, middle and west have passed the test at the significance level of 10%, indicating that China's agricultural green total factor productivity has a significant positive spatial spillover effect. The agricultural green total factor productivity of the provinces included in the three regions of the east, the middle and the west is affected by various factors in the region where the province and the neighbouring provinces are located. The openness and inclusiveness of modern agricultural production and management make the input–output relationship of agricultural production in different provinces complex. Differences are significant in the factor input ratio because of their different locations. The eastern provinces have more advantages in agricultural infrastructure, education and training than the central and western provinces. They will adopt more modern agricultural science and technology in their modern agricultural production, pay attention to the development of eco-friendly agriculture, accelerate the R&D and application of agricultural green science and technology and, thus, drive the advantage of a strong economic foundation in attracting agricultural production and management talents and adopting agricultural-production technology innovation. Finally, the agricultural technology progress in other regions will be realised through the agricultural green technology spillover. The allocation structure of various factor resources in the east, the middle and the west regions will be optimised. The agricultural green total factor productivity will be promoted through the sharing of green agricultural science and technology.

Table 4. Spatial panel regression results and robustness test of agricultural green total factor productivity under factor market distortion.

	Spatial Regression Results				Stability Test			
	Eastern Provinces	Central Provinces	Western Provinces	Whole Country	Eastern Provinces	Central Provinces	Western Provinces	Whole Country
Factor market distortion	−0.135 *** (0.189)	−0.172 * (30.584)	−0.083 ** (6.547)	−0.157 ** (0.931)	−0.249 ** (0.254)	−0.188 ** (24.413)	−0.102 * (6.472)	−0.193 ** (1.269)
Rural human capital	0.355 *** (1.357)	0.452 * (5.376)	0.128 ** (2.985)	0.109 *** (3.457)	0.137 *** (4.572)	0.225 *** (11.453)	0.038 ** (3.458)	0.134 ** (0.587)
Scale of rural financial development	0.092 *** (4.566)	0.075 ** (5.774)	−0.132 ** (3.876)	0.245 *** (6.921)	0.121 *** (5.456)	0.364 *** (9.785)	0.278 *** (3.457)	0.105 *** (4.231)
Agricultural-trade openness	0.024 *** (4.561)	0.147 ** (1.843)	0.023 * (1.248)	0.015 *** (4.561)	0.027 *** (3.445)	0.182 * (2.056)	0.064 *** (2.479)	0.023 *** (3.455)
Agricultural-scale management level	0.106 *** (3.451)	0.112 ** (9.712)	0.052 ** (8.731)	0.031 *** (4.560)	0.117 *** (3.079)	0.157 *** (5.078)	0.035 *** (5.357)	0.084 *** (4.541)
Regional industrialization level	0.051 *** (3.254)	0.008 ** (8.488)	0.011 ** (1.982)	0.005 * (4.547)	0.012 *** (3.547)	0.024 *** (6.175)	0.013 ** (3.795)	0.026 ** (4.789)
Adjustment of agriculture-related policies	0.037 *** (5.457)	0.107 ** (1.478)	0.131 ** (2.334)	0.142 *** (6.451)	0.037 *** (4.533)	0.166 *** (9.772)	0.128 *** (3.842)	0.086 *** (4.551)
ρ	0.541 *** (6.477)	0.223 ** (2.487)	0.294 ** (1.993)	0.207 ** (1.850)	0.324 ** (2.142)	0.203 * (1.377)	0.187 ** (1.589)	0.199 * (1.854)
θ	0.021 *** (6.116)	0.199 ** (3.142)	0.034 ** (3.478)	0.215 * (1.555)	0.012 * (1.914)	0.281 *** (8.877)	0.057 ** (3.101)	0.132 ** (2.009)
Hausman	31.716	281.268	24.174	23.808	30.447	270.017	23.207	22.856
R2	0.776	0.769	0.765	0.806	0.840	0.719	0.827	0.774
Wald	30.762	260.614	24.535	25.835	29.532	250.189	23.554	24.801
p value	0.000	0.003	0.000	0.000	0.000	0.003	0.000	0.000
LR	30.879	261.604	24.628	25.933	29.644	251.140	23.643	24.896
p value	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000

***, **, * are significant at the level of 1%, 5% and 10%, respectively.

Table 4 shows that the factor market distortion variable coefficients of the three regions in the east, the middle and the west are all negative values. The significance test at the 10% level shows that various factor market distortions widely existing at this stage significantly negatively impact agricultural green total factor productivity. The inhibition effect of factor market distortion in the central provinces is the largest, followed by the eastern and western provinces. Given factor market distortion and other reasons, a certain mismatch is found in the key factor resources of modern agricultural production, which means that factor market distortion in different regions hinders the improvement in agricultural green total factor productivity to a certain extent. To eliminate the negative impact of factor market distortion on agricultural green total factor productivity, only by continuously deepening the reform of the factor market; realising the free trade of various factor markets and the free flow of various agricultural-production factor resources across regions to a certain extent; and reducing the degree of factor market distortion can we optimise the factor allocation structure and efficiency in modern agricultural production with the help of the factor market. Finally, the green total factor productivity of agriculture will be improved. Table 4 shows that the impact of rural human capital on agricultural green total factor productivity is significantly positive at the 10% level. Thus, with the improvement in rural human capital, more and more new green technologies can be widely adopted, effectively improving agricultural green total factor productivity. The impact of the scale of rural financial development on the agricultural green total factor productivity of eastern and central provinces is significantly positive at the level of 10%. However, it inhibits the growth of the agricultural green total factor productivity of western provinces, indicating that the western provinces have leaked the funds gathered by the western provinces to a certain extent with the improvement in the level of rural financial development. Furthermore, the eastern and central provinces have absorbed the surplus funds of the western provinces because of high capital prices. Thus, the results of rural financial development in different regions vary. Table 4 shows that the impact of agricultural-trade openness, agricultural-scale operation level, regional industrialisation level and agricultural-related policy adjustment on agricultural green total factor productivity is significantly positive at the 10% level, which all contribute to the improvement in agricultural green total factor productivity, but there are also significant regional differences. The effect of eastern provinces is significantly better than that of central and western provinces.

This study uses the reciprocal of the geographical distance between the capitals of 28 provinces (cities and autonomous regions) as the geographical weight matrix to verify the robustness of the spatial regression model, as shown in Table 4. The influence of factor market distortion on agricultural green total factor productivity is significantly negative at the level of 10%, indicating that factor market distortion will hinder the improvement in agricultural green total factor productivity, which is consistent with the estimation result using the geographical distance between provincial capitals as the weight matrix. Other variables have significantly promoted the growth of agricultural green total factor productivity at the 10% level, which is close to the result of the spatial regression equation; the empirical result of spatial regression is significantly robust.

3.2.2. Spatial Spillover Effect of Agricultural Green Total Factor Productivity under Factor Market Distortion

Table 5 shows that the direct and indirect effects of factor market distortion on this province and neighbouring provinces show a negative impact at the 5% significance level. Therefore, only by continuously deepening the reform of factor markets such as capital, labour and land and reducing the degree of factor market distortion can we effectively improve the agricultural green total factor productivity of this province and neighbouring provinces and optimise the total factor productivity of other neighbouring regions. The direct effect of factor market distortion is significantly higher than its indirect effect. That is, the factor market distortion in the province has a greater impact on the inhibition of agricultural green total factor productivity growth in the province, and the factor market distortion in neighbouring provinces has a weaker effect on agricultural total factor productivity in the province. Therefore, balancing and optimising the process of factor market reform in the three regions, reducing the degree of factor market distortion in different regions and the spatial spillover effect of factor market distortion, and realising the synchronous and balanced growth of agricultural green total factor productivity in different regions are necessary. Table 5 shows that the direct and spillover effects of rural human capital, agricultural trade openness, agricultural scale operation level, regional industrialisation level and agricultural policy adjustment on agricultural green total factor productivity are all positive at the 10% significance level. The direct effect of the scale of rural financial development on agricultural green total factor productivity is positive, while the spillover effect is negative. Therefore, although rural financial development can effectively promote the improvement in agricultural green total factor productivity in the province, it hinders the improvement in agricultural green total factor productivity in neighbouring provinces to a certain extent. Although agricultural-trade openness and agricultural-related policy adjustment can improve agricultural green total factor productivity in this province and neighbouring provinces, the significance is low, and the improvement effect is not apparent.

Table 5. Spatial effect decomposition of agricultural green total factor productivity under factor market distortion.

Variable	Direct Effect	Indirect Effect	Total Utility
Factor market distortion	−0.021 ** (3.117)	−0.009 ** (2.451)	−0.030 *** (3.851)
Rural human capital	0.027 *** (4.045)	0.019 ** (6.487)	0.046 ** (1.762)
Scale of rural financial development	0.034 ** (1.578)	−0.032 * (1.497)	0.066 ** (2.134)
Agricultural-trade openness	0.021 * (1.688)	0.011 * (1.725)	0.032 ** (2.241)
Agricultural-scale management level	0.041 *** (3.748)	0.005 ** (1.978)	0.046 *** (3.108)
Regional industrialization level	0.005 *** (3.166)	0.009 * (1.663)	0.014 ** (2.175)
Adjustment of agriculture-related policies	0.029 * (1.457)	0.035 * (1.588)	0.064 ** (1.789)

***, **, * are significant at the level of 1%, 5% and 10%, respectively.

4. Research Conclusions and Policy Implications

In this study, considering the unexpected output, such as carbon emissions and agricultural non-point-source pollution, the Malmquist productivity index is constructed by using the non-radial and non-angle SBM directional distance function to measure the agricultural green total factor productivity of 28 provinces (cities and autonomous regions) from 1997 to 2020. Finally, the spatial Dobbin model is used to explore the spatial impact of agricultural green total factor productivity under the distortion of the factor market. The results show that the agricultural green total factor productivity considering the unexpected output, such as carbon emissions and agricultural non-point-source pollution, is more in line with the actual level of China's agricultural high-quality green development than the total factor productivity without considering environmental factors. Whether the unexpected output is included, most of the increase in China's agricultural total factor productivity comes from agricultural technological progress, and the boost of agricultural technological progress and technical efficiency is lower. Insufficient technical efficiency inhibits the significant increase in agricultural total factor productivity. Although the agricultural green total factor productivity shows an increasing trend, the growth rate is slow, and different regions show significant differences. Factor market distortion has a negative impact on agricultural green total factor productivity. Most of the other variables significantly improve agricultural green total factor productivity but also have a certain spatial spillover effect, which hinders the synchronous growth of agricultural green total factor productivity in different regions. China has significant regional differences. The market level of different regional factors, the level of agricultural production and the endowment conditions of resource factors all show gradient differences between the east and the west. Therefore, starting from the current reality of China's agricultural production, adopting differentiated development policies, formulating various policies and measures to improve agricultural green total factor productivity under the distortion of factor market and in combination with the characteristics of different regions, and implementing precise policies to promote the comprehensive and balanced increase in agricultural green total factor productivity in different regions are urgently needed. Therefore, the policy implications of this study include the following four aspects.

Firstly, the mode of agricultural production must be changed and green agricultural production promoted. Under the guidance of the 'two mountains' concept, the green production factor input combination is adopted to reduce effectively the unexpected output level, such as environmental pollution caused by agricultural production. It ensures that rural ecology is not damaged, realises the transformation from agricultural ecological resource value to economic value, and steadily improves the agricultural ecological environment effect. We will vigorously change agricultural green production technologies, continue to promote technological innovation in agricultural production, give full play to the role of various policies in promoting agricultural green production, optimise the technical efficiency of agricultural production, and achieve a steady and substantial increase in agricultural green total factor productivity driven by technological progress and technical efficiency. Therefore, to change the agricultural-development mode from extensive to intensive, we must simultaneously improve technological progress and technological efficiency. Through the profit-seeking mechanism, we should mobilise the enthusiasm of agricultural producers and establish a good system so agricultural-production technology can spread faster and better among agricultural producers.

Secondly, the regional pattern of agricultural production must be optimised, and the regional gap in agricultural total factor productivity arrowed. We will continue to increase the adjustment of agriculture-related policies, give full play to the spatial spillover effect of various resource elements, formulate reasonable regional agricultural development strategies, and promote the spatial gradient transfer of agricultural-production efficiency from eastern provinces to central and western provinces through agricultural-production technology assistance and management and operation teaching. We will encourage all kinds of talents to return home and start businesses through various policies, address the shortage of high-quality agricultural talents, give play to the scientific and technological progress effect of high-quality agricultural development and comprehensively balance the overall efficiency of China's agricultural production. The overall awareness of agricultural practitioners for green and low-carbon agriculture will determine their emphasis and ultimately assess their enthusiasm to change the mode of production.

Thirdly, the reform of various factor markets in different regions must be comprehensively deepened, along with the blocking effect of factor market distortion on the improvement in agricultural green total factor productivity. The experience and practice of the market-oriented reform of factors in the eastern provinces will be extended to the central and western provinces, and relevant policies in different regions will be coordinated. Market means are used to optimise the allocation of various agricultural-resource elements and realise the market value of factor resources through the free flow between regions and within regions. The input–output structure of agricultural-production resources is optimised, the allocation efficiency of agricultural-production resources in different regions is comprehensively improved, various regional comparative advantages of China's agricultural production are realised, and the effective growth of agricultural green total factor productivity is boosted.

Lastly, various agricultural security measures must be optimised, and a policy system for the high-quality green development of modern agriculture should be established. We will optimise green-production subsidies for various agricultural policies; improve the supporting infrastructure for green agricultural development; provide a series of supporting funds, technologies and equipment for green agricultural development; and reduce the damage of agricultural production to environmental resources. We will optimise the support for agriculture-related green finance, improve the development level and efficiency of rural green finance, ensure that all kinds of financial institutions prioritise supporting green agricultural production and operation entities, and solve problems such as the shortage of funds in green agricultural production. We should vigorously improve the level of rural human capital, promote the transformation of farmers' identity, let more people with ability and ideas join the farmers' profession, lay a talent foundation for the development of modern green agriculture, accelerate the application of various agricultural green technologies, and realise the improvement in the agricultural green economic effect.

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