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Does FDI Promote or Inhibit the High-Quality Development of Agriculture in China? An Agricultural GTFP Perspective

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Abstract: This paper innovatively brings the undesirable output of agricultural carbon emission into the agricultural Total Factor Productivity (TFP) accounting framework as a measure of Green Total Factor Productivity (GTFP) and uses the Slack-based Measure and Malmquist-Luenberger (SBM-ML) index method to measure the agricultural GTFP of 24 provinces in China from 2004 to 2016. Further, the two-step system generalized moment method (GMM) is adopted to reveal the effect of agricultural (Foreign Direct Investment) FDI on the growth of agricultural GTFP and various subitems. We find that the average annual growth rate of agricultural GTFP is 3.1%, and its contribution rate to agricultural growth is 52%; the growth of agricultural GTFP shows that the progress of agricultural technology is accompanied by the deterioration of agricultural technical efficiency; the agricultural GTFP in the Eastern region, the Central region and the Western region increases in a stepped-up form, with an annual growth rate of 3.1%, 3.3% and 3.4%, respectively. Agricultural FDI has a significant promoting effect on agricultural GTFP and subitems, however, it has an inverted U-shaped feature in the long term.

Keywords: agricultural FDI; green total factor productivity; Malmquist-Luenberger index method; two-step system GMM

1. Introduction

The improvement of Total Factor Productivity (TFP) should be regarded as the source of driving force for the high-quality economic development in China, which was pointed out in the report of the 19th National Congress of the Communist Party of China. TFP denotes the contribution of intangible factors other than tangible production factors such as labor, capital and land, to economic growth. Intangible factors usually include technological progress, rational allocation efficiency of factors, continuous innovation of organizations, and the differences thereof, explain the tremendous differences in the quality of economic growth among countries and regions.

The traditional TFP accounting cannot systematically reflect the quality level of economic development, because it ignores the undesirable output of environment, e.g., carbon emissions and air pollutants. Oskam first incorporated environmental pollution into the agricultural TFP estimation, by taking the negative external effects caused by air pollution, surface and groundwater pollution, soil pollution and the destruction of natural landscape into consideration [1]. Meng endowed the green factor productivity and measured natural resource productivity and TFP by using the Ecological Carbon Footprint method [2]. Li and Xu proposed the concept of Green Total Factor Productivity (GTFP), which not only introduced variables reflecting environmental changes but also served as indicators to measure and evaluate economic development [3]. Agriculture, a basic sector of the national economy, is currently facing the "time window" for the transformation from "high-yield" agriculture to "high-quality" and "green" agriculture. This highlights the importance of improvement of agricultural GTFP in promoting the agricultural supply-side structural reform, agricultural quality improvement and efficiency change in China, as well as realizing rural revitalization and farmer welfare growth.

However, since the reform and expansion, a continuous net flow of the agricultural high-quality production input factors into industrial sectors is witnessed, resulting from the long-standing implementation of the unbalanced development strategy of "city preference and industry priority" and market-oriented reform of factors. This status is still not fundamentally reversed despite the vigorous implementation of a series of national policies with aims to "enhance agriculture" and "benefit the farmers" [4]. Moreover, there are prominent problems in China's agricultural development structure, such as low comparative benefits of agriculture, insufficient supply of high-quality agricultural products, structural surplus of agricultural products and food safety.

Since agricultural production input factors are reduced, and transformation and upgrading are faced with great pressure, it is obvious that the improvement of GTFP will become an inevitable choice and feasible path for the high-quality development of China's agriculture at present and in the future. The questions that we need to answer are: what are the temporal and spatial characteristics of agricultural GTFP in China? What is the heterogeneity of agricultural GTFP in regions, such as the difference of technical change (TC) and efficiency change (EC)? What are the logical motivations behind it? The pragmatic response to the above questions has important theoretical and practical significance to the improvement of agricultural GTFP in China.

With the acceleration of China's expansion process, its agriculture has gradually integrated into the global division of labor and cooperation system. Particularly, after joining the World Trade Organization (WTO) in 2001, in compliance with its commitment of expansion and relevant WTO rules, the Chinese government has gradually lowered the access threshold of the agricultural market. China's agriculture GTFP growth should not only exploit potentialities inside but also seek impetus by expanding the growth and introducing foreign investment.

Foreign Direct Investment (FDI) has gradually penetrated China's agricultural sector, and the utilization of foreign capital of agriculture in China has been increasingly expanded. The used amount of FDI in China's agriculture jumped to 1897.7 million dollars in 2016 from 898.73 million dollars in 2001, with an increase of 111.16% and an average annual growth of 5.11%, calculated according to the data released by the National Bureau of Statistics (NBS). The agricultural FDI has expanded to late-developing regions such as Hubei, Hunan, Guangxi, Chongqing, Guizhou and Xinjiang in central and western China from the economically developed areas such as Guangdong, Jiangsu, Zhejiang, Fujian and Shanghai which are frontiers of the reform and expansion. Also, with the gradual expansion of China's development from the Eastern region to the Central and Western regions, the growth rate of agricultural FDI in the Central and Western regions is significantly faster than that in the Eastern region. Based on the data from NBS, the mean value of agriculture FDI for sample provinces in the Eastern region increased from 68.88 million dollars in 2004 to 161.53 million dollars in 2016, with an average annual growth rate of 11.21%, while the mean value of agriculture FDI for sample provinces in Central and Western regions sharply rose from 41.38 million dollars and 9.94 million dollars in 2004 to 263.98 million dollars and 102.57 million dollars in 2016, with an average annual growth rate of 44.83% and 77.66% respectively, and on the absolute number of mean value for agriculture FDI in the sample provinces, the value in the Central region is 1.63 times higher than that of the Eastern region.

Although the Eastern region is an initial gathering place of investment for agricultural FDI, the industrial layout adjustment, that is, the manufacturing and modern service industry, are prioritized as leading sections and have produced a significant crowding-out effect on the agriculture FDI. With the implementation of regional development strategies such as "Rise of Central China", and "the Belt and Road", the transport infrastructure and public service construction in Central and Western regions have been upgraded significantly, the regional condition disadvantages tend to be more effective in relieving, and the investment environment has been improved significantly. Also, major agricultural provinces or grain-producing areas are mainly located in the Central and Western regions, thereby promoting the agricultural FDI to penetrate towards and accumulate in the Central and Western regions.

It is observed from specific investment fields or projects that, in the Eastern region, agricultural FDI is mainly invested in the fields of efficient horticulture planting, deep processing of agricultural and sideline products, and sales and circulation of agricultural products; in the Central region, agricultural FDI is mainly invested in the development of agricultural land and the construction of large-scale comprehensive agricultural facilities; in the Western region, agricultural FDI mainly involves husbandry, dairy products and other fields. Agricultural FDI has become an important indispensable force in the supply, production, processing, logistics distribution and export of agricultural production materials in China.

With the gradual formation of an all-round, multilevel and wide-range expansion agricultural framework, the agricultural FDI is becoming an important variable that affects the high-quality development of China's agriculture. Then, what impact does the extensive "penetration" of FDI into China's agriculture have on agricultural GTFP? An inhibiting impact or a promotional one? The answer to this question has rich policy implications in terms of evaluating the level of agricultural FDI in China at the present stage, directing agricultural expansion to the outside world, and optimizing the allocation of FDI among regions and industries in China.

Therefore, to address the above questions, this paper brings the undesirable output of agricultural carbon emission into the agricultural TFP accounting framework, adopts the Slack-based Measure and Malmquist-Luenberger (SBM-ML) index method to measure the agricultural GTFP and 24 provincial samples of China from 2004 to 2016, and analyze its evolution trajectory and regional differences. Further, this paper reveals the effect of agricultural FDI on GTFP and various sub-items by adopting the Two-Step System Generalized Moment Method (GMM).

2. Literature Review

The impact of FDI is mainly reflected in the TFP, TC, and EC. Some scholars argued that FDI promotes technological progress in home countries, and FDI has a significant technology spillover effect [5–8]. The other scholars studied the impact of FDI on TFP of the host country and found that FDI has an external spillover effect, which has a significant positive impact on TFP [9–16]. Wang and Wang showed that FDI in the service industry has significantly inhibited the growth of GTFP in the service industry in China and the Central and Western regions [17]. Some scholars showed that FDI can effectively promote the improvement of TFP and EC in the manufacturing industry [18,19]. However, some scholars thought that the effect of FDI on GTFP is not significant and has significant heterogeneity [20,21].

The above research on the relationship between FDI and TFP mainly involves manufacturing, service industry and environment, but there is less research on agriculture. Whether agricultural FDI can effectively promote agricultural TFP growth in inflow regions has been widely concerned in recent years, and has obtained rich theoretical or empirical results, forming two completely different views or propositions.

The first view believes that agricultural FDI has a positive impact on the agricultural TFP of inflow countries or regions and is supported by a large of empirical evidence or experience. Investors are increasingly renting or purchasing the farmland abroad considering the food crisis and limited natural resource in the host country [22]. Adom et al. explored how FDI mitigates the impact of public (Research and Development) R&D on agricultural production by using the data of 28 countries in Africa from 1980 to 2014 and the fixed-effect model, and found that FDI has a direct positive impact on agricultural production [23]. Jiang et al. discussed the actual impact of China's agricultural FDI and concluded that private enterprises are the pillar of China's agricultural FDI, and agricultural FDI guarantees national food security through expanding the agricultural market, and brings agricultural technology, management experience, and employment opportunities.

The second view is that agricultural FDI has no significant or even inhibitory effect on agricultural TFP growth [24]. Using the panel data from 10 sectors of China's agricultural products processing industry from 2007 to 2012, Lin et al. showed that Taiwan's direct investment has not brought direct technology spillover effect on the agricultural product processing industry in mainland China, but it can improve the degree of overseas openness of the agricultural product processing industry in mainland China and narrow the technological gap between the two sides of the mainland [25]. Alfaro found that agricultural FDI had a negative effect on agricultural production efficiency by using the data of OECD countries [26]. Owutuamor et al. used the Ordinary Least Square (OLS) and Granger Causality Test to study the impact of FDI on agricultural growth in Nigeria, and found that agricultural FDI had a certain inhibitory effect on agricultural growth [27]. Meng and Li adopted the Data Envelopment Analysis (DEA) method to study the relationship between agricultural FDI and agricultural TFP in 15 provinces in China from 2000 to 2011, and found that agricultural FDI had a significant negative impact on agricultural TFP, and had no obvious promoting effect on technical progress [28]. By introducing the data of bilateral FDI flows from 108 host countries and 240 home countries from 1990 to 2012, Demir et al. used various estimation techniques and a large number of robustness tests and found that bilateral FDI flows had no significant impact on two host countries. Finally, this paper failed to find the effect of agricultural productivity growth or convergence [29].

Existing literature has important references or inspirations for the study, however, there is still room for improvement: firstly, environmental factors, especially the undesirable output of carbon emission, were not included when calculating agricultural TFP, and only the impact of agricultural FDI on agricultural TFP under the desirable output was studied. Secondly, agricultural TFP was not decomposed to further describe the possible heterogeneity of agricultural FDI on various subitems. Agricultural TFP could be further decomposed into the agricultural TC and EC. Obviously, based on studying the overall effect of agricultural FDI on agricultural TFP, it may have more policy implications to further study the influence of agricultural FDI on various subitems of agricultural TFP and reveal the heterogeneity that might exist.

3. Agricultural GTFP Measurement

3.1. SBM-ML Method

Two kinds of methods are mainly used to measure TFP. One is the parametric method based on the production function hypothesis, such as the Cobb-Douglas (C-D) Production Function [30] and the Arithmetic Index Number (AIN) [31], which has the advantage of effectively identifying the random factors. However, it requires a more accurate setting of the model and is only applicable to the case with a large sample size, otherwise, it will easily lead to the deviation of estimation results. The other is the nonparametric technical efficiency method based on the relative comparison between the evaluated objects, which is represented by the exponential decomposition under the Data Envelopment Analysis (DEA) [32] and the Stochastic Frontier Analysis (SFA) [33,34]. The DEA, a deterministic method, usually assumes that producing more output relative to fewer input resources is a criterion of efficiency and can effectively reduce the model bias caused by function setting. To avoid the defects of the ML index method and Modification Indices (MI) index method, this paper introduces the SBM-ML model based on the DEA index method. The method solves the measurement problem of the input and output slack under undesirable output, and further decomposes the TFP growth factors [35,36]. This method is used to measure the agricultural GTFP in 24 provinces of China.

Each province is a production unit, and it is assumed that the information on the input used by a production unit, $X = \{x_1, x_2, \ldots, x_N\} \in R_+^N$, the desirable output by the production unit $Y = \left\{y_1, y_2, \ldots y_Q\right\} \in R_+^Q$, and the undesirable output by the production unit, $B = \{b_1, b_2, \ldots, b_L\} \in R_+^L$, is available. Suppose the returns to scale are variable, the SBM directional distance function [37,38] is defined as follows:

$$D_V^t\left(x_i^t, y_i^t, b_i^t\right) = \widehat{p} = \min \frac{1 - \left[\frac{1}{N}\sum_{n=1}^{N}\frac{s_n^x}{x_n^i}\right]}{1 + \left[\frac{1}{Q+L}\left(\sum_{q=1}^{Q}\frac{s_q^y}{y_q^i} + \sum_{l=1}^{L}\frac{s_l^b}{b_l^i}\right)\right]} \tag{1}$$

$$s.t.\begin{cases} \sum_{i=1}^{I} z_i^t y_{i,q}^t - s_q^y = y_{i,q}^t, q = 1, 2, \ldots, Q; \\ \sum_{i=1}^{I} z_i^t x_{i,n}^t + s_n^x = x_{i,n}^t, n = 1, 2, \ldots, N; \\ \sum_{i=1}^{I} z_i^t b_{i,l}^t + s_l^b = b_{i,l}^t, l = 1, 2, \ldots, L; \\ \sum_{i=1}^{I} z_i^t = 1, z_i^t \geq 0, s_q^y \geq 0, s_n^x \geq 0, s_l^b \geq 0, i = 1, 2, \ldots I \end{cases} \tag{2}$$

In Equation (1), $\widehat{p}$ is the efficiency evaluation index; x_i^t is the input of province i; y_j^t is the desirable output of province i; b_i^t is the undesirable output of province i; s_n^x is excesses in input, s_q^y is the shortages of desirable output, s_l^b is the excesses of undesirable output; the DMU is efficient in the presence of undesirable outputs if and only if $\widehat{p} = 1$, i.e., $s_n^x = 0$, $s_q^y = 0$, $s_l^b = 0$; z_i^t is weight vector.

Given the above definition of the SBM directional distance function in period t, this paper defines the SBM-ML index for adjacent reference from t to $t + 1$, further decomposing the SBM-ML index into the TC index and the EC index, which can be expressed as:

$$\begin{aligned} (SBM-ML)_t^{t+1} &= \left[\frac{D_V^t\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^t\left(x^t, y^t, b^t\right)} \times \frac{D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^{t+1}\left(x^t, y^t, b^t\right)}\right]^{1/2} \\ &= \frac{D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^t\left(x^t, y^t, b^t\right)} \times \left[\frac{D_V^t\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)} \times \frac{D_V^t\left(x^t, y^t, b^t\right)}{D_V^{t+1}\left(x^t, y^t, b^t\right)}\right]^{1/2} \\ &= Ec_t^{t+1} \times Tc_t^{t+1} \end{aligned} \tag{3}$$

If SBM-ML > 1, TC > 1, and EC > 1, representing the agricultural GTFP, technical progress and technical efficiency are improved from period t to $t + 1$; if SBM-ML < 1, TC < 1, and EC < 1, representing the agricultural GTFP, technical progress and technical efficiency are deteriorated from period t to $t + 1$.

3.2. Input and Output Variables and Data Sources

3.2.1. Agricultural Output

The value-added of the primary industry is used as the desirable output variable of agriculture. The value-added of the primary industry within the reporting period (one year) is the residual value of the gross output value of the current price of the primary industry deducting the intermediate consumption of the primary industry. Compared with the gross output value of the current price of the primary industry, the value-added of the primary industry eliminates the effect of the intermediate consumption and can better describe the real output of input factors. The data of the value-added of the primary industry used by this paper comes from the NBS.

The agricultural carbon emission is used as the undesirable output proxy variable of agriculture. The undesirable output of agriculture is mainly reflected in the agricultural carbon emission caused by the six factors, i.e., pesticide, chemical fertilizer, diesel oil, agricultural film, irrigation and turning over [37,38], and the accounting equation is:

$$E = \sum_{i}^{n} E_i = T_i \times \sigma_i \tag{4}$$

where, E is the total carbon emissions from agricultural production activities, E_i is the emissions of each carbon source i, T_i is the original amount of each carbon emission source, σ_i is the emission coefficient of each carbon emission source, and the determination of carbon emission factors is shown in Table 1.

Table 1. Determination of agricultural carbon emission factors.

Carbon Emission Source	Carbon Emission Coefficient	Source of Reference Value
Pesticide	4.9341 kg/kg	Oak Ridge National Laboratory in the USA (Li et al. [39])
Diesel oil	0.5927 kg/kg	IPCC [39,40]
Agricultural film	5.18 kg/kg	Institute of Resource, Ecosystem, and Environment of Agriculture, Nanjing Agricultural University [40]
Chemical fertilizer	0.8956 kg/kg	Oak Ridge National Laboratory in the USA (West TO et al. [41])
Irrigation	266.48 kg/hm^2	Duan Huaping et al. [42]
Turning over	312.6 kg/hm^2	Wu Fenlin et al. [43]

Data source: according to relevant references. IPCC is the Intergovernmental Panel on Climate Change.

3.2.2. Agricultural Input

Labor, land, machinery, chemical fertilizer and irrigation are selected as agricultural inputs. The number of employees in the primary industry is used as agricultural labor input. The sown area is selected as the variable of land input to better reflect the actual utilization rate of land. Agricultural machinery refers to the sum of mechanical power used in agriculture, forestry, animal husbandry, and fishery production. This paper uses the total power of agricultural machinery to represent the level of agricultural mechanization. Chemical fertilizer refers to the volume of effective component of nitrogenous fertilizer, phosphate fertilizer, potash fertilizer, and compound fertilizer. The effective irrigated area is used as irrigation input. Under normal circumstances, the effective irrigated area is the sum of water fields and irrigated fields where irrigation system or equipment has been installed for regular irrigation purpose. It is an important indicator to reflect the farmland water conservancy construction in China. The data of the above five input variables are from China Statistical Yearbooks from 2003 to 2016 and the provincial statistical yearbooks. A small amount of missing data is calculated by the interpolation method.

3.3. GTFP of 24 Sample Provinces in China

Using the agricultural input and output data of 24 sample provinces in China from 2003 to 2016, the agricultural GTFP index is calculated by MaxDEA 8.0 software. The growth rate and decomposition index of the overall agricultural GTFP in China are obtained, as shown in Table 2.

From 2004 to 2016, the agricultural GTFP index for all other years was greater than 1 except for 2005 and 2010. The average value of agricultural GTFP is 1.031 with an average annual growth rate of 3.1%, indicating that the agricultural GTFP shows an overall growing trend in the past 10 years. The agricultural TC index is greater than 1 in all years with an average value of 1.046, indicating agricultural technology has made significant progress. However, the average agricultural EC index is 0.996 (annual average growth of −0.4%), indicating the growth of agricultural technology progress is accompanied by the deterioration of agricultural technical efficiency. Therefore, the GTFP growth is mainly driven by technological progress rather than technical efficiency improvement, that is, the GTFP growth is characterized as an "outward shift" of the production frontier boundary rather than "catch-up" of it. The average annual growth rate of value-added in the primary industry of the 24 sample provinces in China is consistent at 9.2% from 2004 to 2016, and the average annual growth rate of GTFP is 3.1%. Therefore, the average annual contribution rate of GTFP growth to the growth of value-added in the primary industry is 52%, indicating GTFP growth is the core driving force for agricultural growth.

Table 2. Overall agricultural Green Total Factor Productivity (GTFP) growth rate and its decomposition factors of 24 sample provinces in China from 2004 to 2016.

Year	EC	TC	GTFP	GDP Growth Index of the Primary Industry	Contribution Rate of GTFP to the GDP Growth of the Primary Industry
2004	1.035	1.024	1.057	1.032	1.781
2005	0.938	1.031	0.963	1.079	−0.468
2006	1.020	1.013	1.033	1.053	0.623
2007	0.958	1.073	1.023	1.172	0.134
2008	1.124	0.959	1.067	1.171	0.392
2009	0.990	1.041	1.029	1.067	0.433
2010	1.021	1.023	0.999	1.156	−0.006
2011	1.009	1.005	1.012	1.171	0.070
2012	0.959	1.081	1.033	1.110	0.300
2013	0.902	1.205	1.062	1.068	0.912
2014	0.944	1.119	1.050	1.060	0.833
2015	1.030	1.000	1.030	1.033	0.909
2016	1.023	1.023	1.044	1.052	0.846
Average value	0.996	1.046	1.031	1.092	0.520

Data source: the author calculated and compiled according to relevant methods. Note: the contribution rate of TFP to the GDP growth of the primary industry = (TFP growth rate-1)/(GDP growth rate of the primary industry-1); the value-added index of the primary industry takes the previous year as the base period, using the index value of GDP growth in the current year/the index value of GDP growth in the previous year.

Furthermore, this paper measures and decomposes the agricultural GTFP of 24 sample provinces respectively to investigate the possible heterogeneity of agricultural GTFP growth in different regions. The results are shown in Figure 1 below. Firstly, the agricultural GTFP growth indexes of 22 provinces, except Shanghai and Guangxi, are greater than 1, but the growth rates are significantly imbalanced. The top four provinces are Jiangsu (1.088), Shandong (1.059), Chongqing (1.056) and Xinjiang (1.055) respectively. The bottom four provinces are Shanghai (0.966), Guangxi (0.984), Hunan (1.017) and Guangdong (1.017) respectively. Secondly, the TC indexes of the sample provinces, except Shanghai (0.996), are all greater than 1. The agricultural EC indexes of 9 provinces are greater than 1, while the rest 15 provinces are less than 1, indicating the agricultural technical efficiency in most provinces is stagnating or deteriorating. Thirdly, the agricultural GTFP in the Eastern region, the Central region and the Western region increases in a stepped-up form, with an annual growth rate of 3.1%, 3.3% and 3.4%, respectively. Thus, the best growth performance of agricultural GTFP occurs in the Western region, while the worst in the Eastern region. Fourthly, EC is higher than TC in the Central region, while EC is lower than TC in the Eastern and Western regions.

Most provinces in the Central region are major grain-producing areas with flat terrain, with a higher land circulation rate. The efficiency on scale and specialization of agricultural production are outstanding to enable the improvement of EC and contribution to the GTFP growth exceeds the technology progress. The technology advantages and talent resources in the Eastern region, at the forefront of reform and expansion, are more outstanding. A large number of agricultural scientific research institutes and agricultural technology research and development centers gather here, so that the agricultural knowledge and technology spillover effect promotes the increase of agricultural TC. Meanwhile, the area of farmland, taken up by the development of manufacturing industry dominated by the export-oriented processing industry, decreases. Compared with the Central region, the scale and specialization of agricultural production and operation are not enough to restrict the improvement of EC. Most provinces in the Western region are located in the mountainous areas with less developed economy, and EC improvement has been limited to land scale, therefore, the growth of GTFP can only be driven through agricultural technology progress.

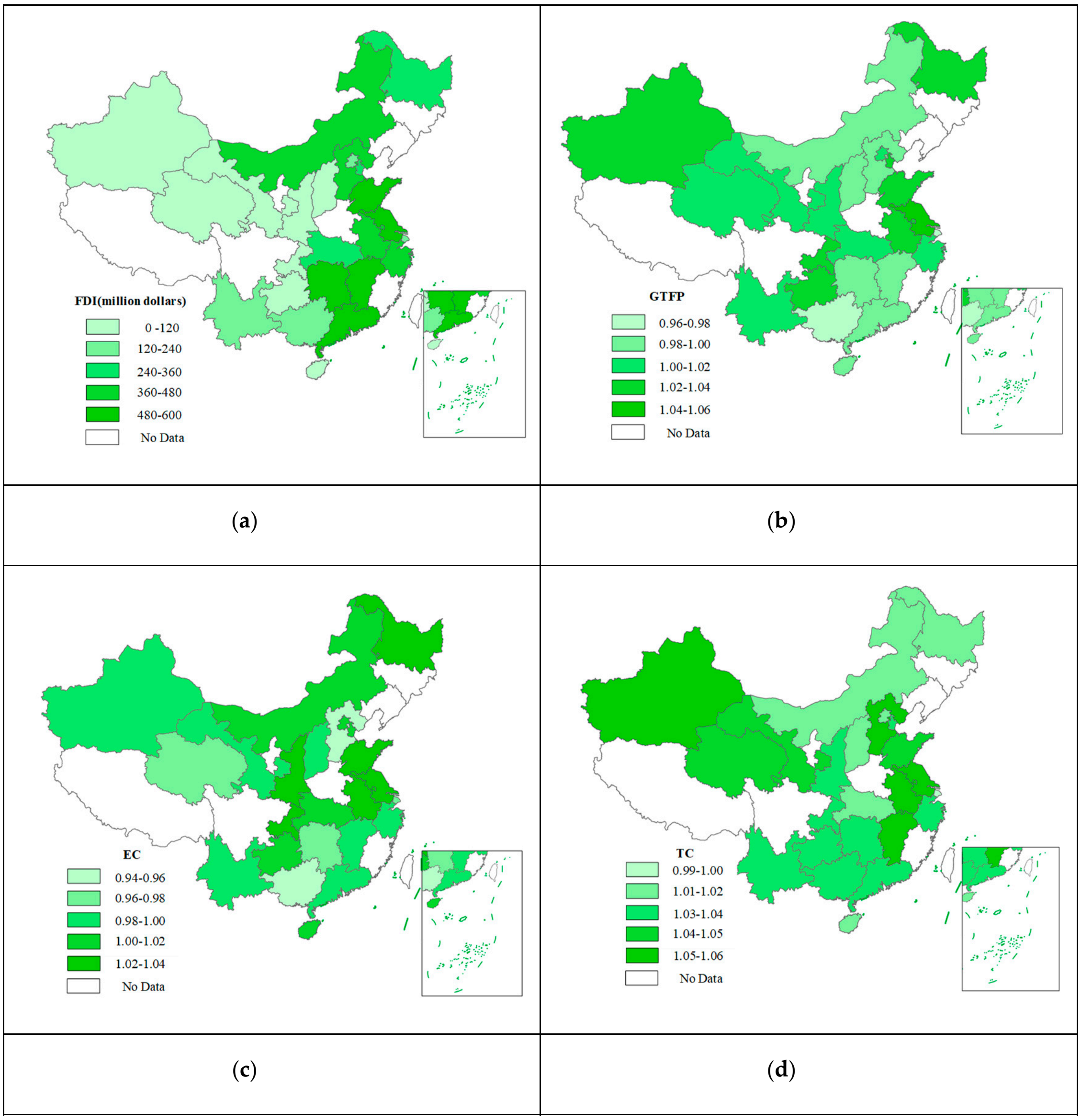

Figure 1. Distribution of the agricultural (Foreign Direct Investment) FDI, GTFP, efficiency change (EC) and technical change (TC) in 24 provinces from 2014 to 2016. Data source: The author calculated according to relevant methods, drawing the figure by using Arcgis10.6 software. (**a**) agricultural FDI in 24 sample provinces in China from 2004 to 2016; (**b**) agricultural GTFP in 24 sample provinces in China from 2004 to 2016; (**c**) agricultural EC in 24 sample provinces in China from 2004 to 2016; (**d**) agricultural TC in 24 sample provinces in China from 2004 to 2016.

4. Econometric Model, Variable Definitions, and Data Descriptions

4.1. Econometric Model and Estimation Method

The mixed OLS, fixed effects (FE) [44] and random effects (RE) [45,46] models are the most commonly used estimation methods for panel analysis. However, if the explanatory variables themselves are endogenous, the parameter estimation results of the above three models may be biased and inconsistent. As a consistent estimate, GMM requires instrumental variables to be strictly exogenous and highly correlated with endogenous variables. The Difference GMM and System GMM improved on the basis of GMM can significantly improve the estimation effect [47–49]. The System GMM takes the lagged dependent variable and endogenous (predetermined) independent variable after difference as instruments of corresponding variables in the level equation and takes lagged dependent variable and endogenous independent variable after leveling as instruments variables of corresponding variables in the difference equation. Then, the final GMM estimation results of the level equation system are obtained by weighting after estimating and identifying the parameters of the level equation and difference equation. Compared with the Difference GMM, the System GMM has a smaller deviation and improved efficiency in the limited sample estimation. Besides, it is also helpful to alleviate the possible weak instruments and limited sample bias in the Difference GMM, and greatly improve the robustness of the estimation. Based on the difference in the selection of the weight model, the System GMM is further divided into a One-Step GMM and Two-Step GMM [49]. The standard covariance matrix of the Two-Step GMM can deal with sequence autocorrelation and heteroscedasticity more effectively, especially when large regional differences exist [50,51].

Previous studies have proved that agricultural TFP in China has significant heterogeneity in the different regions [52–54]. When estimating the impact of FDI on agricultural GTFP, endogenous problems, caused by the autocorrelation between missing variables or explanatory variables and random disturbance items, may exist. Therefore, this paper applies the Two-Step System GMM for estimation, and the specific model is constructed as follows:

$$\begin{aligned}\ln GTFP_{i,t} = \; & \beta_1 \ln FDI_{i,t} + \beta_2 \ln FDI^2 + \beta_3 CZZN_{i,t} + \beta_4 TI_{i,t} + \beta_5 \ln RS_{i,t} + \\ & \beta_6 \ln RS_{i,t-1} + \beta_7 NU_{i,t} + \beta_8 FC + \beta_9 AA + \mu_i + \varepsilon_{i,t}\end{aligned} \tag{5}$$

where $t-1$ is lagged for one period, μ_i represents individual effects on variables, and $\varepsilon_{i,t}$ is a random disturbance term. Agricultural GTFP is the explained variable, agricultural FDI is the core explanatory variable, and the trade structure, residents' saving level, new urbanization, planting structure of the crops and the disaster area are explanatory variables. Considering the long-term influence of agricultural FDI on agricultural GTFP, we add FDI's quadratic component in explanatory variables.

4.2. Definitions of Variables

1. Explained variables: agricultural GTFP, TC and EC

The agricultural GTFP of 24 sample provinces from 2004 to 2016 in China measured by the SBM-ML index method, the TC and the EC are taken as the explained variables respectively.

2. Core explanatory variable: agricultural FDI

Agriculture FDI plays an important role in agricultural economic development and agricultural GTFP growth in terms of the cultivation of agriculture leading enterprises, the extension of agricultural industrial chain and promotion of the integration with the tertiary industry within the primary industry. Since it is difficult to find the capital stock of agricultural FDI in each province, the utilized value of the foreign investment in the primary industry by each province over the years is used as the scale of agricultural FDI.

3. Control variables

Logically, GTFP growth is closely related to regulation or policy environment, production factors devotion and agricultural production structure, and control variables to explain GTFP change could be classified into three categories.

Fiscal agricultural support and agricultural trade openness variables are regarded as the regulation or policy environment. Fiscal agricultural support plays an important role in the supply of public goods such as agricultural infrastructure, expenditure on research and development and public services [50,55]. The increase of financial scale and improvement of allocation efficiency will contribute to the agricultural technical progress and efficiency improvement. This paper uses the national government expenditure on agriculture, forestry, animal husbandry and fishery as the agricultural fiscal support (CCZN). The agricultural trade openness will contribute to the integration of China's agriculture into the process of globalization, which forces China's agricultural producers to adopt the advanced technology and modernistic management style to promote the improvement of local agricultural production and management level. In this paper, the proportion that total import and export trade of the primary industry to the total volume of import and export trade is selected as the agricultural trade openness (TI).

Residents' savings, urbanization level, and crop area covered by natural disaster are selected as the production factors devotion. Residents' savings, as an important source of agricultural investment, is an unattainable driving force for agricultural technical progress and efficiency improvement. Residents' savings (RS) is expressed by the actual deposits of urban and rural residents in financial institutions at the end of the year. Urbanization will change talent structure and factor allocation in China, presenting the non-agricultural transfer of surplus labor in agriculture or rural areas and agricultural capital deepening (capital-labor ratio increases), and drive the development of the agricultural scale and specialization to promote agricultural technical efficiency. This paper selects the proportion of permanent urban residents to the total population (urbanization rate) to measure the urbanization level (NU).

The crop area covered by natural disaster will directly cause the loss of agricultural output value and affect the actual sown area in the short term. However, agricultural technical progress or management improvement could deal with the current loss or potential risk [56]. The crop area covered by natural disaster (AA) is expressed by the proportion of the actual disaster area to the crop sown area.

The planting structure of farm crops represents the agricultural production structure. It draws the allocation of production input factors in farm crops planting [50]. Coupling with market demand will affect the change of agricultural product price or value and reflect the allocation efficiency of agricultural production factors. The planting structure of farm crops (FC) is expressed by the proportion of grain crops acreage to the sown area of farm crops. Among them, the grain crops refer to cereal, barley, beans and oil-bearing crops, and farm crops refer to grain, vegetables, medicines and fruit crops.

4.3. Data Source and Description

This paper covers 24 regions in China from 2004 to 2016. The agricultural FDI data involved are from the statistical yearbooks of each province; the agricultural trade openness, the residential savings, the planting structure of the farm crops and the crop area covered by natural disaster are from the China Statistical Yearbook over the years; the urbanization data comes from the China City Statistical Yearbook. To eliminate the heteroscedasticity and reduce the order of magnitudes, the logarithmic processing is applied to FDI, agricultural fiscal support, residential savings and the crop area covered by natural disaster. Variable explanations and descriptive statistics of variables are shown in Tables 3 and 4 respectively.

Table 3. Variable description.

Variable	Code	Variable Description
Agricultural green total factor productivity	GTFP	GTFP growth index measured by SBM-ML index method
Agricultural FDI	LNFDI	The actual use amount of FDI in the agricultural production (unit: ten thousand dollars)
Square of agricultural FDI	$LNFDI^2$	The square of actual FDI used in the agricultural production (unit: ten thousand dollars)
Agricultural fiscal support	CZZN	The fiscal expenditure on agriculture, forestry, animal husbandry and fishery (unit: one hundred million yuan)
Agricultural trade openness	TI	Proportion of total import and export trade of the primary industry to the total volume of import and export trade
Residents' savings	LNRS	the actual deposits of urban and rural residents in financial institutions at the end of the year
Residents' savings that lag behind for one period	L.LNRS	the actual deposits of urban and rural residents in financial institutions at the previous period
Urbanization level	NU	Proportion of permanent urban residents to the total population
Planting structure of farm crops	FC	Proportion of grain acreage to the crop sown area
Area covered by natural disaster	AA	Proportion of actual disaster area of crops to the crop sown area
Technical progress index	TC	Technical progress index decomposed by the GTFP growth index
Technical efficiency index	EC	Technical efficiency index decomposed by the GTFP growth index

Source: the author compiled.

Table 4. Descriptive statistics of variables.

Variable	Sample Size	Mean	Standard Deviation	Maximum	Minimum
GTFP	312	1.0656	0.0620	1.3850	0.8150
LNFDI	312	10.1998	2.1055	14.1200	3.7120
$LNFDI^2$	312	108.4542	41.0811	199.3738	13.7856
CZZN	312	274.5324	225.4783	10.3559	1008.6
TI	312	114.2299	23.6535	235.0323	46.6363
LNRS	312	8.8523	0.9925	10.9927	5.7014
L.LNRS	288	8.7918	0.9841	10.9580	5.7014
NU	312	0.2637	0.1151	0.6051	0.0892
FC	312	0.6365	0.1236	0.9569	0.3281
AA	312	0.2329	0.1449	0.9357	0.0098
TC	312	1.0534	0.0514	1.2870	0.8940
EC	312	0.9867	0.0587	1.3280	0.7360

Data source: the author calculated by the stata15 software.

SBM-ML is short form of Slack-based Measure and Malmquist-Luenberger.

5. Empirical Results and Discussion

5.1. Results of Model Estimations

A series of test in this paper are carried out by econometrics stata15 software to select an appropriate economic model. The estimation results of Equation (5) are shown in Table 5. The key estimation results of Two-Step System GMM are given in Model IV-VI. In comparison, Model I, Model II and Model III represent the estimation results of the fixed effect, the random effect and the OLS, respectively.

Table 5. Analysis of the impact of FDI on agricultural GTFP.

Variables	Fixed Effects	Random Effects	OLS	Two-Step System GMM		
	Model I	Model II	Model III	Model IV (GTFP)	Model V (TC)	Model VI (EC)
Constant	1.0006 *** (2.09)	0.9920 *** (8.37)	0.9920 *** (8.37)			
LNFDI	−0.1877 (−0.76)	0.0003 (0.01)	0.0003 (0.01)	0.0736 *** (7.8)	0.1071 *** (10.12)	0.1150 *** (5.88)
$LNFDI^2$	0.0013 (0.96)	0.001 (0.1)	0.0001 (0.10)	−0.0038 *** (−10.47)	−0.0056 *** (−10.12)	−0.0050 *** (−7.16)
CZZN	−0.0001 (−1.44)	0.0001 * (2.25)	0.0001 (2.25)	−0.0001 *** (−2.87)	0.0002 *** (4.49)	−0.0002 *** (−4.75)
TI	0.0001 (0.22)	0.0002 (0.85)	0.0002 (0.85)	0.0001 *** (3.09)	0.0005 *** (10.15)	−0.0002 *** (−2.98)
LNRS	0.5452 (0.52)	0.0899 (0.93)	0.0899 (0.93)	0.1282 *** (4.99)	0.5215 *** (11.20)	−0.3250 *** (−10.29)
L.LNRS	−0.0605 (−0.06)	−0.1006 (−1.04)	−0.1006 (−1.04)	−0.0700 ** (−2.19)	−0.4624 *** (−10.09)	0.3452 *** (10.62)
NU	0.4747 (1.54)	0.0777 (1.03)	0.0777 (1.03)	0.2316 *** (2.21)	−0.5494 *** (−4.50)	0.7536 *** (12.01)
FC	0.0411 (0.21)	0.0750 * (1.72)	0.0750 * (1.72)	0.2161 *** (2.21)	−0.1288 ** (−2.21)	0.2843 *** (5.46)
AA	-5.94×10^{-6} (−0.74)	-5.43×10^{-6} (−0.87)	-5.43×10^{-6} (−0.87)	−0.0001 *** (−4.74)	0.0001 * (2.37)	1.28×10^{-6} (0.29)
AR(1)				0.004	0.001	0.003
AR(2)				0.818	0.020	0.853
Hansen				0.996	0.999	0.988

Data source: the author calculated by the stata15 software based on the data. Note: The corresponding T statistic and Z statistic of the regression coefficient are in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

As a consistent estimation, the Two-Step System GMM requires that autocorrelation of random disturbance term and second-order autocorrelation of random disturbance term after the difference do not exist, and the instrumental variable should be exogenous. The various tests of model in Table 5 are good. The Arellano-Bond sequence correlation test cannot reject the null hypothesis that second-order serial autocorrelation does not exist for Model IV; Hansen test shows that the instruments are effective, eliminating the endogenous problem of the model. As shown in Model IV in Table 5, the estimation results of the Two-Step System GMM are more significant compared with Model I, Model II, and Model III.

5.2. Results of the Core Explanatory Variable

The agricultural FDI (LNFDI) has a significantly positive effect on agricultural GTFP, and every 1% increase in agricultural FDI leads to an increase of 0.0736% in agricultural GTFP. There are some reasons for this. Firstly, the agricultural FDI leads to an increase in investment of China's agriculture, which effectively alleviates the shortage of agricultural development funds. Following the urbanization and industrialization, overlapped with the breaking down of the barriers to free capital flow triggered by the financial marketization reform, the agricultural funds, driven by interests, continuously flow to the urban or industrial sectors with relatively high returns. Also, the local government prefer that most financial support invest in the urban sector with high short-term yield and remarkable performance by considering the GDP performance, resulting in the extremely limited support of local finance for agriculture or rural areas [57,58]. Thus, China's agriculture faces long-term fiscal repression or shortage of funds. The agricultural FDI fills the long-term gap between the supply and demand of funds and promotes agricultural GTFP growth.

Secondly, the agricultural FDI brings the advanced technology or management to China's agricultural sector, improves the allocation of human capital, and promotes the agricultural specialization, marketization and moderate scale management, all of which contribute to the growth of agricultural GTFP. This theoretical speculation has also been empirically verified by Sun and Li [59] and Han et al. [60].

Furthermore, the agricultural FDI contributes to the cultivation of modern agricultural industrial organizations and the extension of agricultural industrial chain, thereby promoting the integration of resources within the agriculture and between the agriculture and other industries. Such an allocation effect of agricultural resources also improves agricultural GTFP growth [61].

The coefficient of the square of agriculture FDI is negative (−0.0038), indicating that there is no linear relation between agriculture FDI and agriculture GTFP, while showing the significant inverted U-shaped characteristics, that is, the promotion effect of agriculture FDI to agricultural GTFP is positive before a certain critical point and negative afterwards, showing the factual features of rising initially, and then falling. At the initial stage of the introduction of FDI into China's agriculture, China's agricultural business entities can rapidly improve the overall technical and management level of China's agriculture and bring the late-developing advantages into full play through the short-term technical and management imitate, etc. However, this technical change path does not work in the long run. As time goes by, the marginal effect of the late-developing advantage diminishes, causing the standstill of China's agricultural technical change. The technical progress and efficiency improvement of China's agriculture can be truly realized through the optimal allocation of agricultural factor resources, which is brought by the independent innovation of agricultural technology and the supply-side structural reform of agriculture.

5.3. Results of Control Variables

The agricultural fiscal support (CZZN) has a significant inhibitory effect on agricultural GTFP. The funds for financial support in agriculture are managed by many parties and scattered in use. Occupation, misappropriation and indiscriminate use are severe and an effective performance evaluation mechanism [62] is also lacked, thereby lowering the use efficiency of funds for financial support in agriculture, and failing to promote the growth of GTFP in agriculture. The trade structure (TI) has a significantly positive effect on agricultural GTP. As China's expansion to the outside world widens, the "outgoing" and "introduction" of agricultural products intensifies the international competition and forces local agricultural producers to adopt advanced technology and modern management style, thereby promoting agricultural technological progress and efficiency improvement.

The coefficient of residential savings level (LNRS) is 0.1282, but the coefficient of the residents savings level that lags for one period (L.LNRS) is −0.0700. The rise of residents' savings level in the current period will help achieve agricultural loans and promote the increase of agricultural technology investment. The previous year's residents' savings level helps increase the scale of agricultural investment in that year but will also squeeze the agricultural surplus. Loans offered by the financial system have a "city" preference, and thus the newly increased agricultural investment in that year will be reduced, which produces a negative effect on GTFP growth in the current period. The urbanization (NU) has a positive effect on agricultural GTFP. The urbanization has reduced agricultural surplus labors, increased capital-labor ratio and promoted the capital deepening in the agricultural sector, thereby driving the agricultural scale management and specialization as well as promoting the growth of agricultural GTFP. The coefficient of disaster area (AA) is significantly negative, indicating that the disaster area has an inhibiting effect on the growth of agricultural GTFP. The deterioration of the environment for agricultural production caused by the increase of the disaster area will lead to the decline of agricultural output, restricting the growth of agricultural GTFP to a certain extent.

The coefficient of the planting structure of farm crops (FC) is 0.2161, showing the planting structure of farm crops has a significantly positive effect on the growth of agricultural GTFP. The growth of planting area for grain crops is helpful to release the scale economic effect on production and management, and widen the agricultural mechanization, improving the growth of agricultural GTFP.

5.4. Further Analysis of the Impact of Agricultural FDI on the Subitems of Agricultural GTFP

The previous analysis proves that agricultural FDI has a positive effect on agricultural GTFP. Since agricultural GTFP can also be decomposed into agricultural TC and EC, further analysis of the impact of agricultural FDI on TC and EC to reveal its heterogeneity may have more policy implications. TC is the maximum agricultural output that can be achieved with certain input factors; EC represents the optimal allocation of input factors when cost constrained. We conduct further empirical tests on the above two aspects respectively, and the test results are shown in Model V and Model VI in Table 5. The agricultural FDI still has a positive effect on agricultural TC and EC, but the square of agriculture FDI has an inhibiting effect on above two components, indicating that there is still an inverted U-shaped association between agricultural FDI and agricultural TC and EC.

The agricultural fiscal support (CZZN) has a positive effect on agricultural TC, but has a negative effect on agricultural EC [63,64]. The government financial subsidies for agriculture, including grain subsidies, seed subsidies, machinery purchase subsidies and fertilizers subsidies, etc., strengthens modern agricultural technology equipment and pest control technology, and improves the technical level of the agricultural production and productivity. However, the agricultural financial funds are not properly allocated to agricultural organization innovation, thus, the mismatching funds also inhibits the improvement of production factor allocation efficiency. The agricultural opening to the outside world (TI) has a positive effect on TC while a negative effect on EC, showing that the learning or imitation effect and competition effect caused by agricultural trade openness are more reflected in technological progress.

The effect of residential savings level (LNRS) and its lag term on agricultural TC and EC are the opposite. Residents savings level significantly improves agricultural technology but inhibits the improvement of technical efficiency; while the effect of residential savings level that lags for one period on technical change is negative, and on efficiency change is positive. Urbanization (NU) has a negative effect on agricultural TC growth, and a significantly positive effect on EC growth, indicating urbanization in China still needs to be further explored [65]. The surplus labors in agriculture transfer to the non-agricultural sectors with an acceleration of urbanization, promoting the agricultural capital deepening, and driving agricultural scale management and specialization so as to promote the technical efficiency; while the outflow of high-quality labors from agriculture restricts the agricultural technology progress.

The coefficient of the planting structure of farm crops (FC) on agricultural EC and TC is positive and negative, indicating that it has an inhibitory effect on TC but a positive effect on EC. The adjustment of crop planting structure guided by the increase of grain sowing area can further promote the scale and specialization of agricultural production and operation. However, the production of grain crops has strong land dependence and low technological threshold, and as a result, the agricultural technical progress stagnates or even goes backwards, relatively. Except for the significant promoting effect on agricultural TC, the disaster area (AA) has no significant effect on agricultural EC. The governmental post-disaster support and the producers' disaster reduction actions promote the replacement of production equipment and the introduction of disaster reduction or prevention technologies, thereby improving the technological progress of agriculture. However, the technical efficiency is restricted by the scale growth and the optimization of the management process, thus the disaster cannot significantly improve the technical efficiency.

6. Conclusions and Policy Implications

6.1. Conclusions

The undesirable output of agricultural GTFP is not only the key driving force to promote the high-quality development of agriculture, but also the core index to describe its development level. The SBM-ML index method is used to measure agricultural GTFP in 24 provinces in China from 2004 to 2016, and then the two-step system GMM is adopted to carry out the empirical test on the effect of agricultural FDI on agricultural GTFP.

The average annual growth rate of agricultural GTFP in 24 provinces in China is 3.1% from 2004 to 2016, and its contribution rate to the GDP growth rate of the primary industry is 52%; the growth of agricultural GTFP is mainly brought by agricultural technical progress rather than agricultural technical efficiency improvement, that is, it shows that a fact that the progress of agricultural technology is accompanied by the deterioration of agricultural technical efficiency. The regional differences of agricultural GTFP are obvious, showing the evolution characteristics as follows: the agricultural GTFP in the Western region is higher than the ones in the Central region, and the Central region is higher than the Eastern region.

Agricultural FDI has a significant promoting effect on agricultural GTFP and various sub-items, however, it has an inverted U-shaped feature in the long term. Thus, agricultural FDI will promote the growth of agricultural GTFP in the short term but will inhibit the growth of agricultural GTFP after a certain "critical point". Financial support for agriculture, trade structure, current residential savings level and changes in planting structure of crops have positive effects on agricultural GTFP and technical progress, but inhibitory effects on technical efficiency improvement. The residential savings level which lags behind for one period inhibits GTFP and technical progress but improves the efficiency of technical progress. Urbanization improves GTFP and technical efficiency but inhibits technical progress; disaster area has an inhibitory effect on GTFP while a positive effect on agricultural technology progress.

6.2. Policy Implications

This research not only provides useful guidance for policymakers on how to introduce FDI, but also provides a practical example for economies that are undergoing a similar development stage of China. The agriculture FDI has a significant positive promoting effect on agricultural GTFP, and the expansion of the growth and active introduction of foreign funds in China's agriculture are still the choices to realize the improvement of agricultural technical progress or technical efficiency in China. The access threshold of agricultural FDI should be further lowered, the negative list management of agricultural investment, listing all the management measures not conforming to foreign capital's national treatment and most-favored-nation treatment, should be promoted. The utilization scale of foreign investment in agriculture should be actively expanded, and foreign agricultural enterprises, especially with relatively high technical level, should be attracted to invest to improve the introduction quality of agricultural FDI.

The foreign capital utilization and cooperation mode should be innovated to guide agricultural FDI into China's agricultural producer services, so as to provide technical support and management services for Chinese agricultural business entities or agricultural enterprises. China's agricultural producer services can be exemplified by agricultural materials distribution service, agricultural technology extension service, agricultural information service, agricultural machinery operation service, agricultural product quality and safety service, disease prevention and control service, agricultural product marketing service, infrastructure management and maintenance service, labor force transfer service, financial and insurance service, etc. Through optimizing the hardware or software investment environment, agricultural FDI should be actively guided to flow to the regions with low agricultural development level or backwards technical level, thereby promoting the effective convergence of the regional gap of China's agricultural GTFP.

The relations between agricultural FDI and agricultural GTFP, TC and EC show a typical inverted U-shaped feature. Therefore, while expanding the funds introduction and improving its quality, the linkage and coordination of "government, enterprises, academia, and research institutes" in the agricultural sector should be realized, thereby implementing the connection of agricultural technology research and development with market demand as well as the combination of talent training and industrial needs, so as to ultimately realize the agricultural technical progress and efficiency improvement in China. Moreover, technology introduction should be combined with technology assimilation, absorption and application to improve the assimilation, absorption and independent innovation ability of foreign technologies by cultivating the technical strength and human capital level of agricultural enterprises.

Agricultural technology progress or technical efficiency improvement cannot be separated from the carrier role of modern agricultural industrial organizations. The leading business mode of the "fragmentation" and "home production" of land is useless to the learning and absorption of foreign capital's advanced business philosophy, modern agricultural technology and management experience. The market-oriented mechanism of land circulation should be established and improved; the modern agricultural operation organizations, such as farmers' cooperatives, large plantations and family farms, are developed by guiding the concentration of land, capital and other production factors to operators or farmer-turned-entrepreneurs, which are of important significance to the better utilization of FDI to improve agricultural technical progress and improve agricultural technical efficiency.

The leverage of financial support for agriculture should be actively played. The central and local financial support for agriculture or rural areas should be strengthened, and special efforts should be made to support rural infrastructure construction and public service improvement to provide a good environment for agricultural FDI to participate in rural revitalization. The integrated development of farmers' cooperatives, supply and marketing cooperatives, credit cooperatives and the "three cooperatives" should be promoted through supportive policies of fiscal subsidy, and tax preference and financing assurance, etc., rural or agricultural development factor resources should be integrated, and the effect of resource reallocation should be enhanced.

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