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Evaluation Theory and Empirical Study of Agricultural Total Factor Productivity Based on Eco-Environmental Efficiency Constraints

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Abstract: In order to accurately grasp the growth of agricultural total factor productivity in Jiangxi Province and analyze the impact of agricultural development on eco-environmental efficiency in Jiangxi Province, this paper uses Malmquist-Luenberger index to introduce eco-environmental efficiency constraint into the analysis framework of agricultural total factor productivity. The agricultural total factor productivity and its decomposition components of 11 cities in Jiangxi province from 2000 to 2015 under the constraint of eco-environmental efficiency were calculated and analyzed, and the convergence analysis of agricultural total factor productivity of Jiangxi Province was conducted. The results show that: Efficiency of ecological environment in jiangxi province in 2000-2015 under the constraints of agricultural total factor productivity is not present decline during the period of stable growth and show the local features of agricultural total factor productivity of agriculture in jiangxi province output growth contribution rate is extremely low, from a technical progress and technical efficiency improvement effects on agricultural total factor productivity growth are not regular, There are regional differences in agricultural total factor productivity of jiangxi province, especially fuzhou and Ganzhou, which are not ideal. Under the constraint of eco-environmental efficiency, agricultural total factor productivity of Jiangxi Province shows the characteristics of club convergence. Based on the above analysis, relevant policy implications are proposed.

1. Introduction

In the report, General Secretary proposed for the first time "implementing the rural revitalization strategy" and "improving total factor productivity and establishing a modern economic system." These are the overall plans and solid arrangements for agricultural economic development in the new era. Green agriculture is at the forefront of modern agricultural development, is also a new era under the strategy of rejuvenating rural agriculture industry development inevitably choice, as a result, the efficiency of the ecological environment under the constraint of total factor productivity of agriculture, the study has important strategic significance for the agricultural industry towards high efficiency, high quality and low consumption of green development path to provide science policy basis.

The research achievements of the current academic circles to the agricultural total factor productivity is quite rich, throughout the agricultural total factor productivity measurement and evaluation, can be divided into two categories, one kind is the traditional agricultural total factor productivity measurement, namely, considering only the production factors as input constraints and ignore the influence of the resources and environment for the agricultural total factor productivity and constraints; The other is to consider resource and environment factors in the framework of agricultural total factor productivity analysis. At present, the research on agricultural total factor productivity using the traditional total factor productivity research method is still the mainstream. In terms of the research on agricultural total factor productivity, except for a few scholars who think that agricultural pollution has little impact on agricultural total factor productivity (Wang Qi, 2012) [1], most studies show that, Environmental constraints will affect agricultural total factor productivity to a certain extent. Therefore, evaluation methods of agricultural total factor productivity that ignore ecological environment constraints are likely to misjudge or overestimate the development trend and speed of China's agricultural growth [2]. Therefore, in recent years, the academic circle has begun to pay extensive attention to the impact of environment on agricultural total factor productivity, and bring environmental factors into the research framework of agricultural total factor productivity. The total factor productivity of agriculture is studied in the context of environmental constraints. The accounting problem of environmental pollution accompanying agricultural production is a difficult and focal issue. The accounting methods adopted can be summarized as follows: First, growth accounting method is adopted. For example, Liu Zhijian (2015) used this method to calculate agricultural total factor productivity by introducing the evaluation value of agricultural pollutants and the cost of agricultural environmental pollution control as input factors into the model [3]. Secondly, using the method of listing, which is now more widely used methods, such as the study on modern hotel groups (2014), such as Tang Dexiang (2016) is to use this method to evaluate agricultural non-point source pollution and introduces its "not" desirable valuation model, through the direction of distance function is calculated under the restriction of resources and environment of agricultural total factor productivity [4,5]; Thirdly, convert or deal with agricultural production factors that may affect the environment, such as the amount of fertilizer input in the agricultural production process. For example, Xue Jianliang (2011) converted the amount of agricultural fertilizer application into the amount of nitrogen and phosphorus loss in agricultural production activities, and used THE amount of nitrogen and phosphorus loss as the main variable of agricultural production pollution to calculate agricultural total factor productivity [6]. Yue Li (2013) took the conservation of materials as the principle. Nitrogen and phosphorus, nutrients of traditional factors in agricultural production, are used as input and introduction models to calculate agricultural total factor productivity [7]. Under the constraints of resources and environment, most studies on agricultural TFP take agriculture as the research object in China. However, due to different research methods and different measurement of agricultural environmental pollution, the specific measurement results of agricultural TFP considering environment also differ greatly [8] [1]. However, the research on the development of agricultural industry in Jiangxi province as the research object is relatively scarce, and the agricultural total factor productivity of Jiangxi province as the research focus is even less.

The existing theoretical and empirical research methods have laid a solid foundation for deepening the study of agricultural total factor productivity. At present, the research on agricultural total factor productivity under the constraint of eco-environmental efficiency is still in its infancy, and the exploration of agricultural total factor productivity under the constraint of eco-environmental efficiency at provincial level has yet to be started, and the related policy optimization research based on the quantitative analysis of agricultural total factor productivity needs to be deepened. Jiangxi province as a typical agricultural province in central China, green ecological and jiangxi biggest wealth, biggest advantage, largest brand, based on this, draw lessons from existing theoretical basis, the efficiency under the restriction of the agricultural ecological environment in jiangxi province empirical measure and the comprehensive evaluation on the total factor productivity, thus makes policy implications of increasing agricultural total factor productivity, It has important theoretical and practical guiding value.

2. Selection and Description of Evaluation Indicators

For total factor productivity accounting methods, there are mainly parametric methods and non-parametric methods. Based on parametric methods, specific parameter functions or assumptions need to be set in advance. In this paper, DEA non-parametric method is adopted, that is, linear programming is used to obtain frontier functions. In view of the fact that environmental pollution cannot increase in the same proportion with resource input in the production process, it is more reasonable to consider environmental pollution as "bad" output rather than input factor and "good" output and use DEA model to analyze it. The Malmquist productivity index, which does not require price information, the traditional Malmquist productivity index method, however, can only be limited to the situation where "good" output and "bad" produce the same proportion change, which is inconsistent with the original intention of productivity evaluation. Therefore, In this paper, the improved Malmquist-Luenberger productivity index and directional distance function are used to calculate the total factor productivity of agriculture in Jiangxi Province by simultaneously expanding "good" output and reducing "bad" output with given input.

2.1. Production Possibility Sets Considering Resource and Environmental Factors

The price of resources and environment cannot be obtained, and the traditional total factor productivity accounting method cannot bring it into the analysis framework of productivity. Therefore, it is necessary to construct a production possibility set containing both "good" and "bad" outputs, namely environmental technology. In this paper, each city in Jiangxi province is regarded as a decision-making unit, and each decision-making unit uses N kinds of inputs to produce M kinds of "good" outputs and I kinds of "bad" outputs, which are denoted as production possibility set:

$$P(x)=\{(y,b): x can produce (y,b)\}, x\in R_{+}^{N}.$$

If the following conditions are met:
(1) Closed and convex sets;
(2) Zero combination of good output and bad output: if, and, then;
(3) Joint weak disposability: if and, then;
(4) Free disposal of inputs and "good outputs": if and or, then.
Assuming that the input-output vector of the decision-making unit k (k=1, ⋯; k) in the period t (t=1, ⋯; t) is, environmental technology can be modeled as:

$$P^t\left(x^t\right)=\left\{\begin{array}{l}\left(y^t,b^t\right):\sum_{k=1}^{K}\lambda_k^t y_{km}^t \geq y_{km}^t, m=1,\cdots,M; \\ \sum_{k=1}^{K}\lambda_k^t b_{ki}^t = b_{ki}^t, i=1,\cdots,I; \\ \sum_{k=1}^{K}\lambda_k^t x_{kn}^t \leq x_{kn}^t, n=1,\cdots,N; \\ \lambda_k^t \geq 0, k=1,\cdots,K\end{array}\right\}$$

2.2. Directional Distance Function

Chung [9] and Fare [10] constructed directional distance function according to Luenberger [11] [12]'s idea of shortage function: (3)

In Formula (3), is the input and output vectors, and is the direction vector of output expansion. The directional distance function measures the probability of "good" output expanding and "bad" output decreasing in a given direction, input and environmental technology structure. For a given input, "good" output increases proportionally and "bad" output shrinks proportionally, which is the maximum possible amount of growth and decrease. Directional distance function uses nonparametric linear programming technology to measure the distance between a single decision making unit and the environmental output frontier in a certain period. The core idea of directional distance function is to require both "good" output to increase and "bad" output to decrease. Shephard [13] output distance function, which constructs traditional Malmquist productivity, represents increasing "good" and "bad" outputs proportionally as much as possible without considering reducing "bad" outputs. The difference between Shephard and directional distance function can be expressed in Figure 1. For an output observation point A, the maximum output point obtained by Shephard distance function is C, and C is efficient. The maximum output point obtained by directional distance function is C, which requires A to increase Y according to the direction vector and decrease B at the same time, so as to reach the production frontier B.

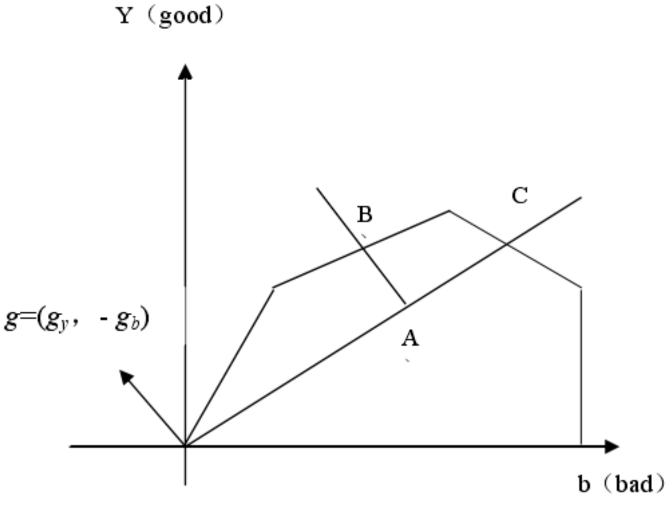

Figure 1: Schematic diagram of Shephard distance function and directional distance function

2.3. Malmquist-Luenberger Productivity Index

According to the method of Fare et al. [14], the concept of intertemporal dynamics is introduced. Taking t period as the base period and from T period to T +1 period, the total factor productivity index based on output and considering the environment can be expressed by Malmquist-Luenberger productivity index:

$$ML_t^{t+1}=\left[\frac{1+\vec{D}_i^t\left(x^t,y^t,b^t;g^t\right)}{1+\vec{D}_i^t\left(x^{t+1},y^{t+1},b^{t+1};g^{t+1}\right)}\times\frac{1+\vec{D}_i^{t+1}\left(x^t,y^t,b^t;g^t\right)}{1+\vec{D}_i^{t+1}\left(x^{t+1},y^{t+1},b^{t+1};g^{t+1}\right)}\right]^{\frac{1}{2}}$$

$$=\left[\frac{1+\vec{D}_i^{t+1}\left(x^t,y^t,b^t;g^t\right)}{1+\vec{D}_i^t\left(x^t,y^t,b^t;g^t\right)}\times\frac{1+\vec{D}_i^{t+1}\left(x^{t+1},y^{t+1},b^{t+1};g^{t+1}\right)}{1+\vec{D}_i^t\left(x^{t+1},y^{t+1},b^{t+1};g^{t+1}\right)}\right]^{\frac{1}{2}}\times\left[\frac{1+\vec{D}_i^t\left(x^t,y^t,b^t;g^t\right)}{1+\vec{D}_i^{t+1}\left(x^{t+1},y^{t+1},b^{t+1};g^{t+1}\right)}\right]=MLtech_t^{t+1}\times MLeffch_t^{t+1}$$

When productivity increases; when productivity declines. Malmquist-luenberger productivity index can be decomposed into technological progress rate index and technological efficiency change index

According to the method of Yang Jun and Shao Hanhua [15], solving malmquist-Luenberger productivity index requires the use of non-parametric linear programming technology to calculate four directional distance functions, which can be obtained by solving the linear programming model of Equation (6) and replacing t of Equation (6) with T +1. Similarly, it can be obtained by solving the linear programming model of Equation (7), and can be obtained by exchanging t and t+1 of Equation (7).

$$\begin{cases}\vec{D}_0^t\left(x^{t,k'},y^{t,k'},b^{t,k'};y^{t,k'},-b^{t,k'}\right)=Max\beta\\ s.t.\sum_{k=1}^{K}\lambda_k^t y_{km}^t\geq(1+\beta)y_{k'm}^t,m=1,\cdots,M\\ \sum_{k=1}^{K}\lambda_k^t b_{ki}^t=(1-\beta)b_{k'i}^t,i=1,\cdots,I\\ \sum_{k=1}^{K}\lambda_k^t x_{kn}^t\leq x_{k'n}^t,n=1,\cdots,N\\ \lambda_k^t\geq 0,k=1,\cdots,K\end{cases}$$

$$\begin{cases}\vec{D}_0^{t+1}\left(x^{t,k'},y^{t,k'},b^{t,k'};y^{t,k'},-b^{t,k'}\right)=Max\beta\\ s.t.\sum_{k=1}^{K}\lambda_k^{t+1} y_{km}^{t+1}\geq(1+\beta)y_{k'm}^t,m=1,\cdots,M\\ \sum_{k=1}^{K}\lambda_k^{t+1} b_{ki}^{t+1}=(1-\beta)b_{k'i}^t,i=1,\cdots,I\\ \sum_{k=1}^{K}\lambda_k^{t+1} x_{kn}^{t+1}\leq x_{k'n}^t,n=1,\cdots,N\\ \lambda_k^{t+1}\geq 0,k=1,\cdots,K\end{cases}$$

Where, represents the weight of the observed value of the KTH sample, and the non-negative weight means that the production technology has constant return to scale.

3. Selection and Explanation of Evaluation Indicators

3.1. Selection and Explanation of Evaluation Indicators

(1) "Good" output

The gross output value of agriculture, forestry, animal husbandry and fishery was selected as the "good" output index, and the year 2000 was taken as the base period, and the price was adjusted by the gross output value index of agriculture, forestry, animal husbandry and fishery.

(2) "Bad" output

Agricultural non-point source pollution was selected as the "bad" output index. Agricultural non-point source pollution refers to the pollution caused to the environment by nitrogen, phosphorus, pesticides and other organic or inorganic pollutants in agricultural production and production activities through water table runoff, farmland drainage and underground leakage. This paper refers to liang Liutao [16]'s idea of using inventory analysis method to calculate Agricultural non-point source pollution in China. Taking the cities of Jiangxi province as accounting units, combined with the principle of data availability, the three types of pollutants including chemical oxygen demand (COD), total phosphorus (TP) and total nitrogen (TN) in the sewage production units of farmland fertilizer and livestock and poultry breeding are mainly analyzed to calculate the agricultural non-point source pollution in the cities of Jiangxi Province. The calculation formula of emissions of various agricultural non-point source pollution and standard agricultural non-point source pollution [2] is as follows:

$$E = \sum_i EU_i \left(1 - \eta_i\right) C_i \rho_i$$

$$EI = E / S$$

Where is the agricultural non-point source pollution emission, is the statistics of non-point source pollution unit I, is the utilization efficiency coefficient of pollution unit I, and is the amount of pollution production, is the emission coefficient of pollution unit I, is the pollution intensity coefficient of pollution unit I; Is the standard pollution discharge of agricultural non-point source pollution, is the evaluation standard of each pollutant discharge. This paper adopts the class III water quality standard in GB3838-2002, in which the evaluation standard of COD pollutant discharge is 20mg/L, TP is 0.2mg/L, TN is 1mg/L.

(3) Factor input

Labor, land, electric energy, agricultural machinery and chemical fertilizer were selected as input variables of agricultural total factor productivity. As one of the input factors, labor is replaced by the number of people employed in agriculture, forestry, animal husbandry and fishery by the number of people employed in the primary industry. Although this will overestimate the elasticity of labor output to some extent, considering that the number of people employed in the primary industry accounts for a large proportion, its impact will be small. The cultivated land area cannot reflect the land input of agricultural production, so this paper uses the total sown area of crops as the land input. The input of agricultural machinery is calculated by the total power of agricultural machinery, while the input of chemical fertilizer is calculated by the discount stock of chemical fertilizer.

3.2. Data Sources and Statistical Description

The purpose of this paper is to examine the ecological environment in jiangxi province, under the restriction of the agricultural total factor productivity, so the selection of 11 cities in jiangxi province in 2000-2015 agricultural input and output of inter-temporal panel data analysis, all data are derived from the past China's regional economic statistical yearbook, jiangxi statistical yearbook, every city statistical yearbook and yearbook, And statistical Bulletin of National Economic and Social Development over the years.

Table 1: Basic statistical description of variables

The variable name	The mean	The standard deviation	minimum	The maximum
Gross output value of Agriculture, Forestry, Animal Husbandry and Fishery (100 million Yuan)	146.7663	111.3027	15.3577	480.5892
Number of Employed persons in primary Industry (ten thousand)	89.0196	56.4188	19.7600	228.5000
Total Sown Area (1000 Ha)	496.6878	292.9430	116.9000	945.9970
Rural electricity consumption (billion KWH)	5.5830	3.9073	0.4313	20.5868
Total power of agricultural machinery (million kw)	213.1582	162.7141	15.2439	753.0000
Conversion amount of agricultural chemical fertilizer application (ten thousand tons)	11.7902	7.0249	2.4000	24.1122
Standard emissions of non-point Source pollution from Agriculture (100 million cubic meters)	266.7777	181.7102	42.4747	676.0137

Table 1 shows the 11 cities in jiangxi province agricultural input and output variables of simple statistical description, we can preliminary findings, the agricultural development of the 11 cities in jiangxi province in 2000-2015 show that the bigger difference, the ratio of the minimax value of agricultural output in 31, agricultural non-point source pollution emissions standard of minimax value ratio is less than 16, The ratio of maximum to minimum of all factor input variables ranges from 8 to 50. On the one hand, the agricultural development scale and agricultural growth rate of 11 cities in Jiangxi province are greatly different. On the other hand, the resources consumed by agriculture and the ecological environment pollution caused by agriculture in different cities in Jiangxi Province are significantly different. Therefore, in order to reduce the deviation between accounting and actual results, it is necessary to consider the constraint of eco-environmental efficiency when measuring agricultural total factor productivity in Jiangxi Province.

4. Empirical Results and Analysis

In this paper, according to the non-parametric DEA theoretical framework, agricultural non-point source pollution as "bad" output was included in the directional distance function, and the AGRICULTURAL ML index and decomposition of Jiangxi Province under the constraint of eco-environmental efficiency from 2000 to 2015 were calculated by using MATLAB2014a software, so as to evaluate the development of agricultural efficiency in Jiangxi Province from an empirical perspective.

4.1. Malmquist-luenberger Productivity Index and Its Decomposition

This paper calculates the agricultural Malmquist-Luenberger productivity index and its decomposition of 11 cities in Jiangxi province during 2000-2015, and obtains the ML index and its decomposition of the whole province (see Table 2). Cities are ranked from highest to lowest by the annual Malmquist-Luenberger productivity index (see Table 3).

Table 2: Agricultural ML productivity index and its decomposition in Jiangxi Province (2000-2015)

Year	ML index	MLtechindex	MLeffch index	Rate of output growth
2000-2001	1.0033	1.0024	1.0009	0.0299
2001-2002	0.9908	0.9885	1.0023	0.0401
2002-2003	1.0058	1.0011	1.0045	0.0274
2003-2004	1.0117	1.0154	0.9964	0.0801
2004-2005	0.9957	0.9926	1.0032	0.0679
2005-2006	0.9966	1.0002	0.9965	0.0610
2006-2007	1.0189	1.0206	0.9984	0.0420
2007-2008	1.0279	1.0354	0.9929	0.0479
2008-2009	0.9853	0.9892	0.9960	0.0459
2009-2010	1.0090	1.0184	0.9910	0.0400
2010-2011	1.0106	1.0138	0.9970	0.0420
2011-2012	1.0067	0.9956	1.0124	0.0459
2012-2013	0.9877	0.9795	1.0092	0.0448
2013-2014	0.9879	0.9860	1.0020	0.0481
2014-2015	0.9995	0.9973	1.0022	0.0399
2011-2015 On average	0.9955	0.9896	1.0065	0.0447
2000-2015 On average	1.0025	1.0024	1.0003	0.0469

According to the analysis of the results in Table 2, the overall situation of agricultural total factor productivity in Jiangxi Province from 2000 to 2015 under the constraint of eco-environmental efficiency is as follows:

Change from the trend, the 2000-2015 period, based on the efficiency of the ecological environment of jiangxi agricultural total factor productivity does not present a stable growth, but a significant fluctuation in the 16 years, the agricultural total factor productivity rise and fall repeatedly appear alternately, the number of its rise and fall of 8 times and seven times respectively. From 2000 to 2015, the average annual level of agricultural total factor productivity of Jiangxi Province under the constraint of eco-environmental efficiency increased slightly, but the increase was only 0.25%. However, in recent five years, the agricultural total factor productivity of Jiangxi Province under the constraint of eco-environmental efficiency declined as a whole. The average annual change level of agricultural total factor productivity did not increase, but declined.

From the perspective of contribution rate of agricultural total factor productivity to overall agricultural output growth, during the 16 years from 2000 to 2015, the average annual growth rate of agricultural total factor productivity in Jiangxi Province was only 0.25%. During the same period, the average annual growth rate of agricultural output in Jiangxi Province was 4.69%. This indicates that only 5.32% of the output growth from 2000 to 2010 was contributed by the improvement of total factor productivity. It can be seen that under the constraints of eco-environmental efficiency, the agricultural total factor productivity in Jiangxi province is extremely low, and the contribution rate of total factor productivity to the growth of agricultural output in jiangxi province is very small.

From the perspective of the structure of total factor productivity, the ML productivity index was decomposed into technological progress rate index and technological efficiency change index, and it was found that the technological progress rate index and technological efficiency change index also rose and fell alternately, and The Times of rise and decline were 9 and 6 times respectively. From the average level of the 16 years from 2000 to 2015, the growth of agricultural total factor productivity in Jiangxi province is more from technological improvement than technological efficiency. The average annual growth rate of technological progress change index from 2000 to

2015 is 0.24%, while the average annual growth rate of technological efficiency change index is only 0.03%. However, from the composition of the agricultural total factor productivity index of Jiangxi Province under the constraint of eco-environmental efficiency in the past five years, although the overall ML productivity index of Jiangxi Province declined during the five years from 2011 to 2015, However, the change index of technical efficiency in these five years still rose, with an average annual increase of 0.65% from 2011 to 2015. During these five years, the change index of technological progress declined instead of increasing, which inhibited the improvement of agricultural total factor productivity in Jiangxi Province. Therefore, there is no obvious regularity in whether the growth of agricultural total factor productivity in Jiangxi province comes from the improvement of technical efficiency or technological improvement. In different years, the improvement of technical efficiency and technological progress have different effects on the growth of agricultural total factor productivity in Jiangxi Province to different degrees. During 2000-2010, Technological progress plays a more significant role in the growth of agricultural total factor productivity in Jiangxi Province. However, from 2011 to 2015, the change index of technical efficiency was more excellent, and the decline of technological progress variable index inhibited the growth of agricultural total factor productivity in Jiangxi Province.

Table 3: Agricultural ML productivity Index of Different cities in Jiangxi Province (2000-2015)

The sorting	cities	ML index
1	nanchang	1.0115
2	jingdezhen	1.0106
3	yichun	1.0070
4	jiujiang	1.0055
5	pingxiang	1.0052
6	Xinyu	1.0040
7	yingtan	1.0023
8	shangrao	1.0012
9	gian	0.9966
10	Fuzhou	0.9965
11	Gangzhou	0.9871

Table 3 analyzes the regional differences of agricultural total factor productivity in 11 cities in Jiangxi Province. During 2000-2015, 8 cities in Jiangxi Province (Nanchang, Jingdezhen, Yichun, Jiujiang, Pingxiang, Xinyu, Yingtan and Shangrao) showed weak annual growth of agricultural total factor productivity under the constraint of eco-environmental efficiency. Under the constraint of eco-environmental efficiency, the average annual growth level of agricultural total factor productivity in Nanchang, Jingdezhen, Yichun, Jiujiang, Pingxiang and Xinyu was higher than the average annual growth level of overall agricultural total factor productivity in Jiangxi province in the past 16 years. The other three cities in Jiangxi province (Ji 'an, Fuzhou and Ganzhou) showed a weak annual decline in agricultural total factor productivity under the constraint of eco-environmental efficiency. Total factor productivity of agriculture in jiangxi province, on the whole, there are still differences in each region, from the input and output factors of scale, input and output factors of smaller cities in total factor productivity of agriculture slightly tall, a more excellent growth of total factor productivity in agriculture, input and output factors of large cities (e.g., ganzhou) agricultural total factor productivity is lower instead, The average annual change of agricultural total factor productivity is declining, and the average annual growth level of agricultural total factor productivity is not ideal, which indicates that the major agricultural cities and important agricultural production areas in Jiangxi province need to change the agricultural growth mode.

4.2. Environmental Technology Innovator

From the above analysis, the basic situation of agricultural total factor productivity of various cities in Jiangxi province is obtained. The problem that needs further study is which cities in Jiangxi Province are on the production front under the constraint of ecological environment efficiency, so as to become the "best practitioner" of agricultural total factor productivity under the constraint of ecological environment. That is, which cities and regions in Jiangxi province play an important role in promoting the outward shift of production possibility boundary and leading the innovation of agro-ecological environment technology. According to the definition of Fare et al. [17], environmental technology innovators need to meet the following three conditions:

$$\begin{cases} MLtech_t^{t+1} > 1 \\ \vec{D}_0^{t}\left(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}\right) < 0 \\ \vec{D}_0^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}\right) = 0 \end{cases}$$

The first condition indicates that the production possibility boundary expands outward along the direction vector from t period to T +1 period, that is, under the given input, there are more "good" outputs and less "bad" outputs in t+1 period compared with T period. The second condition indicates that after technological progress occurs, production in t+1 period takes place outside the production possibility boundary in T period. The third condition indicates that the environmental technology innovator must be on the production possibility boundary. If these three conditions are met at the same time, the production possibility boundary will shift outward.

Table 4: Environmental technology Innovators constrained by eco-environmental efficiency (2000-2015)

year	Innovative cities
2000-2001	Pingxiang, Xinyu, Jian
2001-2002	Pingxiang, Yingtan
2002-2003	Nanchang, Jingdezhen, Pingxiang, Yingtan
2003-2004	Xinyu
2004-2005	Nanchang, Pingxiang, Xinyu
2005-2006	Jiujiang, Yingtan, Yichun
2006-2007	Jingdezhen, Xinyu and Yichun
2007-2008	jingdezhen
2008-2009	Xinyu
2009-2010	jingdezhen
2010-2011	
2011-2012	
2012-2013	shangrao
2013-2014	Xinyu
2014-2015	Xinyu

Table 4 shows that the efficiency of the ecological environment constraints, a total of nine cities during 2010-2015 mobile production possibility frontier at least once, to promote the production frontier progress, namely in the 16 years a total of nine cities in jiangxi province as the ecological environment under the restriction of the efficiency of agricultural total factor productivity best practitioners, including xinyu (7 times) was the most outstanding, Jingdezhen city (4 times), Pingxiang City (4 times) and Yingtan city (3 times) were the next. It shows that these cities in Jiangxi province pay more attention to the rational use of resources and environmental protection in the agricultural production process, while fuzhou and Ganzhou are 0 times; During the periods 2010-2011 and 2011-2012, no advances in production frontier technology took place. In terms of regional distribution, during the survey period, and the important agricultural production areas of Jiangxi Province (such as Ganzhou, Fuzhou) performance is not ideal. This result is consistent with the analysis results of regional differences in agricultural total factor productivity of 11 cities in Jiangxi Province in Table 4. Compared with cities with larger agricultural development scale, cities with smaller agricultural output scale under the constraint of eco-environmental efficiency perform better in agricultural total factor productivity. This means that the high agricultural output in jiangxi province is the result of high input, high energy consumption and high pollution of traditional input factors.

5. Convergence Test

It can be seen from the calculation results that there is a certain gap in the growth of agricultural total factor productivity among different cities in Jiangxi Province. Will this gap gradually narrow or increase with the passage of time? In this paper, the convergence of agricultural TFP in jiangxi province will be tested.

5.1. Test of σ Convergence

The σ convergence test is to test whether the dispersion degree of agricultural TFP in various cities in Jiangxi province gradually decreases with the passage of time. Based on the practice of Zeng Xianfeng and Li Guoping [18], this paper defines the σ convergence test model of agricultural TFP in Jiangxi Province under the constraint of eco-environmental efficiency as follows:

$$\sigma_t = \left[\frac{1}{K} \sum_{k=1}^{K} \left(ML_{tk} - \frac{1}{K} \sum_{k=1}^{K} ML_{tk} \right)^2 \right]^{\frac{1}{2}}$$

Formula (11) represents the agricultural total factor productivity of the KTH city in period T. If it exists, it means that agricultural TFP under the constraint of eco-environmental efficiency has σ convergence

The ecological environment efficiency under the restriction of the sigma value of TFP of agriculture in jiangxi province, on the whole present a downward trend, this shows that the efficiency of ecological environment under the constraint of total factor productivity of agriculture in jiangxi province are sigma convergence, that is to say, every city in jiangxi province agricultural total factor productivity gap between the shrinking over time. However, the σ value fluctuated significantly in 2003 and 2013, indicating that the σ convergence trend of agricultural TFP was unstable under the constraint of eco-environmental efficiency in Jiangxi Province. In order to investigate the convergence of agricultural total factor productivity in Jiangxi province under the constraint of eco-environmental efficiency more accurately, this paper further conducted the absolute β convergence test with high quantitative degree.

5.2. Absolute β Convergence Test

The β convergence test is to measure whether the cities with lower agricultural TFP in Jiangxi province grow faster than those with higher agricultural TFP. Absolute β convergence means that the agricultural TFP in all cities reach the same steady state level. According to the ideas of Bernard and Jones [19], the absolute β convergence test model of agricultural TFP in Jiangxi province under the constraint of eco-environmental efficiency is defined as follows:

$$\frac{1}{T}\cdot\ln\left(\frac{ML_{Tk}}{ML_{0k}}\right)=\alpha+\beta\cdot\ln ML_{0k}+\varepsilon$$

In formula (12), and respectively represent the agricultural TFP values under the constraint of eco-environmental efficiency in base and end of city K, α and β are parameters to be estimated, and ε is the error term. If, it indicates the existence of absolute β convergence. In order to eliminate the influence of agricultural production cycle fluctuations on the test results, the whole investigation period was divided into three stages: 2001-2005, 2006-2010 and 2011-2015. The mean value of agricultural TFP in jiangxi province from 2001 to 2005 under the constraint of eco-environmental efficiency was taken as the base period value, and the mean value of agricultural TFP in Jiangxi Province from 2011 to 2015 under the constraint of eco-environmental efficiency was taken as the final value for testing. The difference between the two periods is 10 years, so T=10. In this paper, the absolute β convergence test of agricultural TFP in Jiangxi Province was carried out directly, and then the absolute β convergence test was carried out according to the above method to eliminate the influence of agricultural production cycle fluctuations on the test results. The test results are shown in Table 5 below.

Table 5: Absolute β convergence test of agricultural TFP in Jiangxi Province under the constraint of eco-environmental efficiency

	α	β	Adjust the R square	F	Sig.
Direct inspection	0.000	-0.069	0.807	42.807	0.000
Eliminate the impact of production cycle fluctuations	0.000	-0.063	0.302	5.320	0.046

The test results in Table 5 show that the absolute β of agricultural total factor productivity in Jiangxi province under the constraint of eco-environmental efficiency converges significantly, indicating that agricultural TFP in all cities of Jiangxi province tends to the same steady-state level. This is basically consistent with the result of σ convergence test, so it can be considered that there is club convergence phenomenon in the agricultural total factor productivity of Jiangxi province under the constraint of eco-environmental efficiency. This means that the regional difference of agricultural total factor productivity in jiangxi province will not be continuously expanded. As long as the required conditions and time are provided, Jiangxi Province can achieve balanced agricultural development in the whole province.

6. Conclusion and Enlightenment

In this paper, malmquist-Luenberger productivity index was used to comprehensively consider the performance of agricultural economic growth in Jiangxi Province under the constraint of ecological environment, and measure the growth of agricultural total factor productivity in 11 cities of Jiangxi Province from 2000 to 2015 under the constraint of ecological environment efficiency. The following conclusions were drawn:

First, the overall level of agricultural total factor productivity in Jiangxi Province was very low under the constraint of eco-environmental efficiency from 2000 to 2015. From the trend, the change index of agricultural total factor productivity in Jiangxi Province did not show a steady rise, but declined to varying degrees in the past five years. The contribution rate of agricultural total factor productivity to agricultural output growth in Jiangxi province is very low. From the perspective of the structure of agricultural total factor productivity growth, whether it is driven by technological progress or technological efficiency improvement does not show obvious regularity, neither technological progress nor technological efficiency improvement is enough to promote the growth of agricultural total factor productivity in Jiangxi Province. Jiangxi province is facing a severe situation to improve agricultural total factor productivity.

Second, there were significant regional differences in agricultural total factor productivity under the constraint of eco-environmental efficiency in Jiangxi Province from 2000 to 2015. In Jiangxi province, 8 cities showed weak growth of agricultural total factor productivity during the survey period, while 3 cities showed decline in different degrees during the survey period. During the 16 years from 2000 to 2015, 9 cities in Jiangxi province acted as the best practitioner of agricultural total factor productivity under the constraint of eco-environmental efficiency at least once. However, fuzhou and Ganzhou, as major agricultural cities, were not on the growth frontier from 2000 to 2015. The performance of agricultural total factor productivity in these two cities was very unsatisfactory under the constraint of ecological and environmental efficiency, which indicated that Fuzhou and Ganzhou were facing the serious situation of "double deterioration" of agricultural economic growth, resource consumption and environmental damage. The task of balancing agricultural growth with ecological and environmental development is particularly daunting.

Thirdly, under the constraint of eco-environmental efficiency, the growth of agricultural total factor productivity in Jiangxi province showed an obvious convergence trend from 2000 to 2015. Jiangxi agricultural total factor productivity growth have sigma convergence, and passed the absolute beta convergence, a significant absolute convergence, this shows that the total factor productivity of agriculture in jiangxi province regional gap will gradually narrowed, under the condition of the technology needed for proper, jiangxi agricultural total factor productivity development level will be balanced gradually, On the whole, the agricultural total factor productivity of Jiangxi province under the restriction of eco-environmental efficiency presents obvious "club convergence" characteristic.

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