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Research on the Impact of Land Management Efficiency on AGTFP

Zhong Min

School of Economics and Management, Guangxi Normal University, Guilin, 541004, China

Abstract: *In order to study the impact of land management efficiency on agricultural green total factor productivity and its internal logic under the background of digital economy, based on measuring agricultural green total factor productivity by SBM model and GML index, 30 provinces in China from 2011 to 2020 (excluding Tibet, Hong Kong, Macao and Taiwan) were studied. The panel data of the same below) was used to analyze the impact of land management efficiency on agricultural green total factor productivity, and the mechanism of land intensive management efficiency and land scale management efficiency on the impact of land management efficiency on agricultural green total factor productivity was investigated, and the threshold effect model was used to further test the effect. The results showed as follows: 1) Under the background of digital economy, land management efficiency had a significant effect on agricultural green total factor productivity; 2) Land intensive management efficiency and land scale management efficiency have significant mediating effect and masking effect respectively in the process of land management efficiency affecting agricultural green total factor productivity. When the land intensive management efficiency exceeds the threshold value, the promoting effect of land management efficiency on agricultural green total factor productivity is further enhanced. According to the results of this study, we should expand the application scenarios of digital technology in our agricultural modernization construction, strengthen the construction of agricultural data resources, and actively promote the moderately scaled intensive agriculture development.*

Keywords: *agricultural green total factor productivity; land management efficiency; land-intensive operation; land-scale operation*

1. Introduction

The green development of agriculture is the basic requirement for the realization of Chinese-style modernization and the inevitable requirement for the realization of high-quality agricultural development [1]. However, problems such as low comparative income from farming, low efficiency of land management and serious pollution from non-point sources of agriculture still hinder the green development of agriculture [2]. On the one hand, the extensive production mode with high input and high pollution caused by low comparative income from farming will further aggravate the non-point source pollution of agriculture and destroy the agricultural production environment [3]. On the other hand, the low efficiency of land management will also hinder high-quality labor and agricultural capital investment, which is not conducive to the application of digital technology and green production technology in the agricultural sector [4]. To realize the green development of the agricultural sector, it is necessary to enhance the agricultural income and land management efficiency through the application of digital platforms and information technology, so as to enhance the agricultural green total factor productivity. To this end, the Chinese government mentioned in the White Paper on the Development of China's Digital Economy (2022) [5] that it should vigorously promote the digital economy, transform traditional agriculture with new technologies, and realize the deep integration of digital technology and green agriculture [6]. Then, under the background of digital economy, what is the impact of land management efficiency on agricultural green total factor productivity? What is the role of land scale and intensive management efficiency? These are the questions to be addressed in this study. In the key period of the transition from traditional agriculture to green agriculture, it is of great practical significance to explore the impact of land management efficiency on agricultural green total factor productivity and the internal mechanism between land scale and intensive management efficiency under the background of digital economy to promote the green transformation of agriculture.

Existing literature on green TFP mainly focuses on manufacturing [7], industry [8] and circulation [9], and discusses the impact of digital industrialization [10], industrial digitalization [11] and digital governance

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[12] on green TFP. However, few literatures discuss the context of digital economy from the perspective of agriculture. Effect of land management efficiency on agricultural green total factor productivity. Scholars pay more attention to the impact of digital countryside [13-14] and digital inclusive finance [15] on agricultural green total factor productivity. For example, Du Jianjun et al. [13] found that digital countryside can promote agricultural green total factor productivity by promoting the scale management of agricultural subjects and agricultural informatization, and Jin et al. [14] also drew corresponding conclusions. From the perspective of digital inclusive finance, some scholars have found that digital inclusive finance can positively affect agricultural green total factor productivity by improving green technology progress [16], improving green technology efficiency [15] and optimizing agricultural industrial structure. In a broad sense, land management efficiency can be divided into land scale management efficiency representing quantity level and land intensive management efficiency representing quality level [17]. It is worth noting that Wang Jing et al. [18] discussed the nonlinear effect of land management scale on digital economy and agricultural green total factor productivity from the quantitative level, but failed to discuss the internal mechanism of land management efficiency affecting agricultural green total factor productivity from the quality level. However, the Ministry of Agriculture and Rural Affairs emphasized in its policies that it should continue to carry out actions to protect and improve the quality of cultivated land to help rural revitalization [19].

Based on the provincial panel data from 2011 to 2020, this study used SBM model, GML index, entropy method and other tools to measure the agricultural green total factor productivity and land management efficiency of 30 provincial administrative regions in China, and investigated the impact of land management efficiency on agricultural green total factor productivity and regional heterogeneity under the background of digital economy. And explore the intermediary effect and nonlinear effect of land management efficiency. It is expected to provide theoretical support for promoting the coordinated development of digitalization and agricultural greening and improving the level of agricultural green total factor productivity.

2. Theoretical analysis and research hypothesis

The digital economy will promote green total factor productivity in agriculture by promoting the efficiency of land intensive management. First of all, the digital economy can break the information barriers between the two sides of the transaction, which makes the transaction cost of agricultural information close to zero [25]. While improving the production, transportation and storage efficiency of agricultural products, it is also more conducive to the spread of advanced production technology and green production mode among agricultural producers, which can enhance the efficiency of land intensive management. Secondly, the digital economy can use the decentralization and information tracing function of blockchain to improve the low efficiency and high pollution production mode caused by backward agricultural production technology level and management mode, enhance the land output efficiency, and then improve the efficiency of land intensive management. The improvement of land intensive management efficiency can enhance the utilization efficiency of production materials such as pesticides and fertilizers, and improve the level of human capital and pollution discharge monitoring in the agricultural sector. The improvement of land intensive management efficiency can also transform the previous extensive large-scale agriculture into modern agriculture with efficient field management ability, which can enhance land output efficiency and reduce agricultural non-point source pollution under the premise of constant land input intensity, thus improving agricultural green total factor productivity [3].

When the efficiency of land intensive management is low, it often means that the utilization rate of agricultural production factors is low, and the agricultural production mode is more primitive. At this time, despite the development of digital economy, due to the backward agricultural production facilities and low level of human capital, the promotion effect of land management efficiency on agricultural green total factor productivity will be at a relatively low level under the background of digital economy [26,2]. With the continuous development of land intensive management efficiency, agricultural infrastructure construction and human capital level of agricultural producers are also gradually improving, which enables the development results of digital economy to be applied to agricultural production and realize the upgrading of green production technology and pollution emission monitoring, so as to reduce pollution emission and ensure agricultural output without changing factor input [27]. And then improve agricultural green total factor productivity. Based on the above analysis, hypothesis 2 is proposed in this study:

H1: Digital economy will promote agricultural green total factor productivity through land intensive management efficiency. When land intensive management efficiency crosses the threshold value, the

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promotion effect of digital economy will be further enhanced

The digital economy will hinder green total factor productivity in agriculture by promoting the efficiency of land scale management. On the one hand, digital economy can deepen the market-oriented reform of land factors, encourage land circulation by reducing land transaction costs, and thus improve the efficiency of land scale management [25]. On the other hand, the digital economy can use the information traceability function of the blockchain to help financial institutions understand the production situation of farmers and alleviate the credit constraints of farmers, which can promote some agricultural producers to transfer to land and improve the efficiency of land scale management. With the improvement of land scale management efficiency and the further deepening of labor division, the non-agricultural industrial transfer of labor will also accelerate, which will reduce the number of agricultural labor in a certain period [28] and have a negative impact on the total amount of agricultural products, thus inhibiting agricultural green total factor productivity. Accordingly, hypothesis 3 is proposed in this study:

H2: Digital economy will improve agricultural green total factor productivity through land scale management efficiency level

3. Model construction and variable selection

3.1 Model Construction

3.1.1 Benchmark regression model

Theoretical analysis shows that land management efficiency will have an impact on agricultural green total factor productivity. Therefore, this study constructs the following regression model:

$$\mathrm{Y}_{it} = \beta_0 + \beta_1 \mathrm{X}_{it} + \beta_2 X + \mu_i + \varepsilon_{it} \tag{1}$$

Where i is the region, t is the year, and Y is the explained variable; X_it is the core explanatory variable; X is a control variable; μ_i is an unobservable provincial fixed effect. ε_it is a random disturbance term. After adding the time dummy variable and the individual dummy variable for regression, the P-values of the time dummy variable were both greater than 10% and the P-values of the individual dummy variable were significant at the significance level of 5%, indicating that the time fixed effect was not significant in the sample. Therefore, the individual fixed effect model was adopted in this study.

In order to further analyze the internal mechanism of land management efficiency affecting agricultural green total factor productivity, that is, whether intensive management efficiency and scale management efficiency in land management efficiency affect agricultural green total factor productivity under the background of digital economy, this study constructs the regression equation as follows:

$$\mathrm{M}_{it} = \beta_0 + \beta_1 \mathrm{X}_{it} + \beta X + \mu_i + \varepsilon_{it} \tag{2}$$

$$\mathrm{Y}_{it} = \beta_0 + \beta_1 \mathrm{M}_{it} + \beta_2 \mathrm{X}_{it} + \beta X + \mu_i + \varepsilon_{it} \tag{3}$$

In the formula, intensity is the efficiency of land intensive management; landtr is land scale management efficiency. Other parameter values and symbols are consistent with formula (1). Formula (2) ~ (5) will be used in this study to examine the effect mechanism of land management efficiency on agricultural green total factor productivity under the background of digital economy.

3.2 Variable Selection

3.2.1 Explained variables

In this study, by referring to the measurement method proposed by Ma et al. [29], the SBM model and GML index were used to measure agricultural green total factor productivity, agricultural green technology efficiency and agricultural green technology progress. Input and output data were obtained from China Statistical Yearbook [30] and China Rural Statistical Yearbook [31]. Overall, from 2011 to 2020, China's agricultural green total factor productivity continues to improve, with an average annual growth rate of 3.054%, among which the growth rate of agricultural green technology efficiency is 1.096%, and the growth rate of agricultural green technology progress is 1.124%.

3.2.2 Explanatory variable

Land scale management efficiency (landtr) and land intensive management efficiency (intensity). In

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accordance with the scientific, systematic and accessible principles of index selection, combined with the connotation of land scale management efficiency and existing research results [34-35], this study adopts the ratio of the land area of the right to use in each province to the total land area of the province. Land intensive management efficiency (intensity) refers to the degree to which input resources are transformed into output benefits through rational use of land and other production factors, reflecting land quality and use efficiency in agricultural production. Combined with the existing results [36-37], two evaluation index dimensions, including land input level and land output benefit, were constructed to evaluate the efficiency of land intensive management. In order to eliminate the problem of heteroscedasticity, we perform logarithmic transformation of these indexes, and calculate the weight value of each index using the improved entropy method. Finally, we use the multi-factor comprehensive evaluation method to measure the efficiency index of land intensive management (Table 1).

Table 1 Index system for land intensive management efficiency

Target layer	Criterion layer	Indicator factor layer	Calculation formula for indicators	Weight
Land intensive operation efficiency	Land input level	X1 per capita building land area	Urban construction land area/urban population	+0.029 116
		X2 Population density	Population/total land area	+0.085 831
		X3 average fixed asset investment	Fixed assets investment/total land area	+0.081 987
		X4 all employees	Employees in secondary and tertiary industries/total land area	+0.147 095
		X5 Average financial expenditure	Public finance budget expenditure/total land area	+0.156 945
	Land output efficiency	X6 Forest coverage rate	Forest cover/total land area	+0.027 687
		X7 average fiscal revenue	Public finance budget revenue/total land area	+0.198 229
		X8 per capita GDP	Regional GDP/ total land area	+0.151 676
		X9 average exhaust emissions	Emissions/total land area	+0.090 349
		X10 Agricultural utilization rate of land	Agricultural land/total land area	+0.031 084

3.2.4 Control variables

Based on existing research results [38-39], this study introduced the following control variables: 1) urbanization level, measured by the ratio of urban population to total population. 2) The level of financial support for agriculture, measured by the proportion of expenditure on agriculture, forestry and water affairs to GDP. 3) Planting structure refers to the proportion of grain sown area in the total sown area of crops. 4) The level of industrial development is measured by the proportion of the output value of the primary industry to GDP. 5) Disaster rate, measured by the proportion of the affected area in the sown area of crops. 6) Urban income gap, measured by the ratio of urban income to rural income. Considering that the Chinese government has been actively investing funds to accelerate the development of digital economy since 2011, in order to better explore this trend, this study collected statistical data from 30 provinces, municipalities and autonomous regions in China from 2011 to 2020 (the statistical data did not include Tibet, Hong Kong, Macao and Taiwan, the same below), and conducted in-depth research on the results. These include China Statistical Yearbook [30], China Rural Statistical Yearbook [31] and relevant reference materials of the National Bureau of Statistics. A small amount of missing data is filled in by linear interpolation. The statistical characteristics of each variable are shown in Table 2.

Table 2 Descriptive statistical characteristics of variables.

Variable	Symbol	Sample size	Mean value	Standard deviation	Min	Max
AGTFP	AGTFP	300	1.037	0.168	0.521	2.109
Digital economy	dig	300	1.004	0.982	-0.651	4.091
Land intensive operation efficiency	intensity	300	0.097	0.140	0.002	0.856
Land scale operation efficiency	landtr	300	0.267	0.118	0.050	0.592
Level of urbanization	urban1	300	1.004	0.998	0.175	3.513
Financial support for agriculture	finan	300	0.501	0.995	0.264	0.730
Cropping structure	astruc	300	0.659	0.145	0.355	0.970
Level of industrial development	indpw	300	0.248	0.999	0.029	0.528
Disaster rate	affir	300	0.153	0.119	0.000	0.695
Urban-rural income gap	urban2	300	0.590	0.122	0.350	0.896

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4. Empirical analysis

4.1 Test results of digital economy and agricultural green total factor productivity

According to the results of LM test, F test and Huasman test, the fixed effect model was used for regression analysis. After adding time and individual dummy variables for regression, the individual fixed effect of samples was significant, while the time fixed effect was not. Therefore, this study determined to use the individual fixed effect model. Under the background of digital economy in Table 3, the baseline regression results of the impact of land management efficiency on agricultural green total factor productivity are shown in table 3. Under the background of digital economy, the regression coefficient of land management efficiency on agricultural green total factor productivity is positive and significant at 5% confidence level. This shows that the development of digital economy helps to improve the green total factor productivity of agriculture. This is because, with the gradual development of the digital economy, the allocation efficiency of agricultural green production factors will gradually increase, which will not only reduce the application amounts of pesticides and fertilizers, but also realize the popularization of agricultural green production technologies through technology demonstration effect and technology transfer effect, thus improving agricultural green total factor productivity.

Table 3 Results of the baseline regression and mechanism analysis regression.

Variable	AGTFP	intensity	landtr	AGTFP	AGTFP
	0.077**	0.008**	0.013***	0.079***	0.161***
dig	(0.039)	(0.003)	(0.004)	(0.022)	(0.047)
				0.253*	
intensity				(0.148)	
					- 0.769**
landtr					(0.347)
	2.549***	0.802***	- 0.078**	1.245***	1.580
_cons	(0.971)	(0.081)	(0.035)	(0.146)	(0.986)
Control variables	Control	Control	Control	Control	Control
Individual fixed effects	Control	Control	Control	Control	Control
N	300	300	300	300	300
R^2	0.732	0.308	0.729	0.729	0.727

Note:① Model 1 represents the baseline regression results. Models 2 and 3 present the regression results of the impact of digital economy on land-intensive operational efficiency and land-scale operational efficiency, respectively. Models 4 and 5 show the results obtained by separately introducing the variables of land-intensive operational efficiency and land-scale operational efficiency into the baseline regression results. ② *, ** and *** indicate the significant level of 10%, 5% and 1%, respectively. The same below.

4.2 Mechanism test

According to the benchmark regression results, digital economy can significantly improve agricultural green total factor productivity. Then, what is the internal mechanism path of this effect? In order to answer this question, this study discusses the mediating effect from the dimensions of land intensive management efficiency and land scale management efficiency.

The regression coefficient of digital economy on land intensive management efficiency is 0.008, which is significant at 1% level, indicating that when digital economy index increases by 1%, land intensive management efficiency increases by 0.8%. The regression coefficient of land intensive management efficiency on agricultural green total factor productivity was 0.253. At this time, under the background of digital economy, the indirect effect of land management efficiency on agricultural green total factor productivity is 0.002 (0.008×0.253), which is the same direction as the regression coefficient of model 4 digital economy 0.079, that is, the direct effect. Land intensive management efficiency plays a significant intermediary effect in the process of digital economy affecting agricultural green total factor productivity, and hypothesis H1 is verified. The reason is that, on the one hand, digital technology can be better applied in large-scale agricultural production, such as the implementation of information management of agricultural production links, real-time monitoring of fertilizer, pesticide dosage and waste water and gas emissions, which can improve the level of green agricultural development; On the other hand, digital technologies such as remote sensing and the Internet of things can also realize the grid management of cultivated land, prompting the government to increase agricultural subsidies and project support for farmers, and realize the accurate landing of subsidy policies, thus improving agricultural green total factor productivity.

In Model 3, the regression coefficient of digital economy on land scale management efficiency is 0.013, which is significant at 1% level, indicating that every 1% increase of digital economy development index, land scale management efficiency increases by 1.3%. In model 5, the regression coefficient of land scale management efficiency on agricultural green total factor productivity is -0.769. At this time, under the background of developing digital economy, the indirect effect of land management efficiency on agricultural green total factor productivity is -0.010 (0.013×-0.769), which is opposite to the regression coefficient of Model 5 digital economy 0.161, that is, the direct effect is in the opposite direction. Land scale management efficiency plays a significant masking effect in the process of digital economy affecting agricultural green total factor productivity, and hypothesis H3 has been verified. The reason is that the high popularity of digital technology has improved agricultural production technology and efficiency. On the one hand, traditional farmers are constrained by limited education level and human resources, and it is difficult to integrate into the green production mode. The decrease of agricultural human capital leads to the phenomenon of abandonment and tillage, which reduces the growth rate of agricultural green total factor productivity. On the other hand, the digital trading platform promotes the growth of small and medium-sized farmers to improve the scale of agriculture, but farmers do not carry out intensive management according to the characteristics of farming. While increasing agricultural production efficiency, they also increase the use of fertilizers and pesticides and the discharge of agricultural waste gas and wastewater, which hinders the improvement of agricultural green total factor productivity.

In order to further analyze the nonlinear impact of digital economy on agricultural green total factor productivity, this study uses land intensive management efficiency as the threshold variable to conduct threshold regression for digital economy and agricultural green total factor productivity, and the results are shown in Table 4. By observing the P-value in Table 4, it can be seen that under the background of digital economy, land intensive management efficiency has a significant single threshold effect on agricultural green total factor productivity. Therefore, this study constructs a single threshold regression equation as follows:

$$\mathrm{Y}_{it} = \beta_0 + \beta_1 \mathrm{X}_{it}(\mathrm{M}_{it} < \eta_1) + \beta_2 \mathrm{X}_{it}(\mathrm{M}_{it} \geq \eta_1) + \beta X + \mu_i + \varepsilon_{it} \tag{4}$$

Where: η_1 is a single threshold value. Other parameter values and symbols are consistent with formula (1). In this study, formula (6) will be used to test the single threshold effect of land intensive management efficiency on agricultural green total factor productivity under the background of digital economy. Table 5 shows that when land intensive management efficiency is < 0.013, under the background of digital economy, land management efficiency has a positive effect on agricultural green total factor productivity, and its regression coefficient is 0.157, which is significant at 1% level. When land intensive management efficiency is greater than or equal to this threshold value, under the background of digital economy, land management efficiency plays a more significant positive role on agricultural green total factor productivity, and the regression coefficient increases to 0.201, which is significant at 1% level. Compared with the regression coefficient of land management efficiency on agricultural green total factor productivity under the background of digital economy and Table 4, it can be seen that when land intensive management efficiency is lower than the threshold value, the promotion effect of land management efficiency on agricultural green total factor productivity under the background of digital economy is limited. However, when the land intensive management efficiency exceeds the threshold value, the growth effect of land management efficiency on agricultural green total factor productivity is significantly improved under the background of digital economy. The reason for this nonlinear effect is that with the improvement of the efficiency of land intensive management, the digital economy can further make use of corresponding technical means, such as a higher level of human capital, pollution emission detection and efficient field management system, enhance the level of land input and land output efficiency through the learning effect of human capital, and reduce agricultural non-point source pollution. And promote the upgrading of agricultural green total factor productivity. Therefore, we conclude that land intensive management efficiency has a nonlinear regulating effect between digital economy and agricultural green total factor productivity, and H2 is verified.

Table 4 Results of threshold value test

Threshold variable	Threshold type	*P* value	Threshold value	BS iterations	Critical value		
					1%	5%	10%
Intensity	Single threshold	0.000	0.013	300	4.579	2.743	2.157
	Double threshold	0.153	0.012	300	36.932	18.782	8.127
	Triple threshold	0.960	0.308	300	20.361	8.684	6.729

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Table 5 Results of threshold regression estimation

Variable	AGTFP
dig(intensity≤0.013)	0.157***
dig(intensity＞0.013)	0.201***
Control variables	Control
Individual fixed effects	Control
N	300
R^2	0.285
F test	60.480***

5. Conclusions and suggestions

5.1 Conclusion

On the basis of measuring agricultural green total factor productivity by SBM model and GML index, this study analyzed the impact of land management efficiency on agricultural green total factor productivity under the background of digital economy by using panel data of 30 provinces in China from 2011 to 2020. From the perspective of land management efficiency, the effect mechanism of land intensive management efficiency and land scale management efficiency on agricultural green total factor productivity in digital economy was investigated, and the threshold effect model was used to further test the effect. The research data show that: 1) the development degree of digital economy has a promoting effect on agricultural green total factor productivity. 2) Land intensive management efficiency and land scale management efficiency have significant mediating effect and masking effect respectively in the process of digital economy affecting agricultural green total factor productivity. When the land intensive management efficiency exceeds the threshold value of 0.013, the promotion effect of land management efficiency on agricultural green total factor productivity under the background of digital economy is further enhanced.

5.2 Suggestion

Based on the above research, in order to improve the efficiency of agricultural production and promote the development of agricultural modernization, it is suggested to take the following three measures.

First, considering the promotion effect of land management efficiency on agricultural green total factor productivity under the background of digital economy, it is necessary to further accelerate the development of digital economy, apply digital platform and information technology to agricultural production, transform traditional agriculture with new technology, and realize the coordinated development of digital technology and green agriculture through green production concept and green production level. And then improve agricultural green total factor productivity. Second, the empirical results show that land intensive management efficiency has a significant intermediary effect on the process of digital economy affecting agricultural green total factor productivity. After the land intensive management efficiency exceeds a certain threshold value, the effect of land management efficiency on agricultural green total factor productivity will be further improved under the background of digital economy. The government should pay attention to the rational utilization of land resources, and improve the quality and utilization efficiency of cultivated land by deepening the market-oriented reform of land elements and upgrading and upgrading of cultivated land. At the same time, policy documents should be issued to guide agricultural producers to protect cultivated land, expand the implementation of fallow, crop rotation and soil testing and formula fertilization, and improve the human capital level of agricultural producers, in order to promote the improvement of intensive management efficiency of agricultural production. Third, the combination of land scale management efficiency has a significant masking effect on the process of digital economy affecting agricultural green total factor productivity. The government should promote the healthy development of land transfer market, promote the large-scale management of agricultural land, optimize the allocation of resources and improve the efficiency of land use by improving the comprehensive quality and management level of agricultural producers. At the same time, it is necessary to fully consider the characteristics of land and production needs, formulate scientific policies and measures, strengthen land scale management, promote the digital transformation of rural economy and the development of green all-factor production, and achieve sustainable development of agriculture.

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