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Study on the impact of digital economy on the green development of agriculture

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Abstract: In order to study the impact of digital economy on agricultural green development and its internal logic, based on measuring the level of agricultural green development by SBM model and GML index, 30 provinces in China from 2011 to 2020 were selected. (The same below) panel data to analyze the impact of digital economy on the green development of agriculture. The results show that: 1) the development degree of digital economy will significantly promote the green development of agriculture; 2) The improvement effect of digital economy on agricultural green development showed significant heterogeneity in different regions, with the improvement coefficient of 0.137 in the eastern region, 0.115 and 0.319 in the northern and southern parts of the Qinling-Huaihe River Line, and 0.068 in the southeastern part of the Hu Line. This shows that the development of digital economy has promoted the promotion of green agricultural development in the eastern region, the areas on both sides of the Qinling-Huaihe River Line and the areas on the southeast side of the Hu Line. 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.

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]. In order to realize the green development of the agricultural sector, it is necessary to enhance the agricultural income and land management efficiency through the use of digital platforms and information technology, so as to promote the green development of agriculture. 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]. So, what is the impact of the digital economy on the green development of agriculture? In the period of the transition from traditional agriculture to green agriculture, it is of great practical significance to explore the impact of digital economy on the green development of agriculture to promote the green transformation of agriculture.

In this study, the provincial panel data from 2011 to 2020 and the SBM model, GML index and entropy method were used to measure the level of agricultural green development and digital economy in 30 provincial administrative regions across the country, and the impact of digital economy on agricultural green development and regional heterogeneity were investigated. It is expected to provide theoretical support for promoting the coordinated development of digitalization and green agriculture and improving the level of green agricultural development.

2. Theoretical analysis and research hypothesis

The essential characteristics of the digital economy, such as trans-temporal information dissemination, scope economy, low energy consumption and low emissions, can effectively eliminate the problems of low comparative income from farming and serious pollution from agricultural non-point sources, which will have an impact on the green development of agriculture. First of all, the digital economy can realize the spread of information and technology across time and space through scientific and technological innovation platforms. On the one hand, scientific and technological innovation platforms can be combined with agricultural production to bring the concept of green production into agricultural production. On the other hand, with the help of scientific and technological innovation platforms, agricultural enterprises can quickly learn cutting-edge production 7 technologies and apply them to green agricultural production [7], which can reduce the frequency of traditional agricultural production materials such as pesticides and fertilizers, slow down the agricultural emission range, and promote the green development of agriculture. Second, the information traceability function of the digital economy can strengthen the government's environmental supervision function, encourage agricultural producers to control the use of fertilizer, and reduce agricultural non-point source pollution.

Specifically, the development of the digital economy can realize the transformation of modern agriculture to green agriculture by accelerating the construction of digital infrastructure such as blockchain and recording important information of agricultural products in the production link in the blockchain using the information traceability function, which can reduce agricultural non-point source pollution and promote the green development of agriculture [8]. Third, through the information coordination function of the e-commerce platform, the digital economy can redistribute fertilizers and pesticides according to the comparative advantages of the supply side and the demand side of the production factors, improve the efficiency of land management, and enhance the green development of agriculture. This is because the e-commerce platform can realize the efficient docking of market supply and demand information, alleviate the problem of information asymmetry in agricultural production, and enable farmers to make more comprehensive decisions with the obtained information, which can reduce the waste of resources caused by the mismatch of land and mechanical factors, and effectively help the green development and growth of agriculture [9]. Accordingly, hypothesis 1 is proposed in this study:

H1: Digital economy can promote the green development of agriculture

3. Model construction and variable selection

3.1 Model Construction

3.1.1 Benchmark regression model

Theoretical analysis shows that digital economy will have an impact on the green development of agriculture. Therefore, this study constructs the following regression model:

$$\mathrm{Agtfp}_{it} = \beta_0 + \beta_1 \mathrm{dig}_{it} + \beta_2 X + \mu_i + \varepsilon_{it} \quad (1)$$

Where i is the region, t is the year, and Agtfp is the explained variable; dig was 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.

3.2 Variable Selection

3.2.1 Explained variables

In this study, by referring to the measurement method proposed by Ma et al. [10], the SBM model and GML index were used to measure agricultural green development, agricultural green technology efficiency and agricultural green technology progress. Input and output data were obtained from China Statistical Yearbook [11] and China Rural Statistical Yearbook [12]. Overall, from 2011 to 2020, China's agricultural green development continues to improve, with an average annual growth rate of 3.054%, in which the growth rate of agricultural green technology efficiency is 1.096%, and the growth rate of agricultural green technology progress is 1.124% (Table 1).

Table 1: Changes and decomposition of agricultural green total factor productivity in China from 2011 to 2020

Year	AGTFP	AGEC	AGTC
2011	1.074	0.981	1.104
2012	1.094	1.056	1.062
2013	1.101	1.005	1.115
2014	0.999	0.959	1.050
2015	1.001	0.980	1.039
2016	1.045	0.959	1.099
2017	0.986	1.175	0.839
2018	1.001	1.170	0.855
2019	1.027	1.094	0.938
2020	1.032	0.984	1.049

3.2.2 Core explanatory variable

This study draws on the index construction system and measurement methods of Wang Jun et al., Zhao Tao et al. [13,14], and uses objective entropy method to empower and measure digital economy (dig) indicators. The specific indicators are selected as shown in Table 2:

Table 2: Index system for the development of digital economy

Target layer	Criterion layer	Indicator factor layer	Weight
Digital economic development index	Digital economic infrastructure	Optical cable length	+0.041 013
		Software revenue	+0.040 514
	Digital economic industry scale	Output value of information service industry	+0.136 843
		Number of Internet domain names	+0.137 111
	Digital economic application scale	Online mobile payment level	+0.093 084
		Mobile phone penetration	+0.250 314
	Digital economic market scale	Mobile phone penetration	+0.017 356
		Telecommunication traffic	+0.082 814
	Digital economic labor force scale	Internet users	+0.090 972
		Number of employees in information service industry	+0.109 978

3.2.3 Control Variables

This study draws on existing research results [15,16] to introduce 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, and conducted in-depth research on the results. These include China Statistical Yearbook [18], China Rural Statistical Yearbook [17] 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 3.

Table 3: Descriptive statistical characteristics of variables.

Variable	Symbol	Sample size	Mean value	Standard deviation	Min	Max
Agricultural green development	Agtfp	300	1.037	0.168	0.521	2.109
Digital economy	dig	300	1.004	0.982	-0.651	4.091
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

4. Empirical analysis

4.1 Test results of digital economy and agricultural green development

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. The benchmark regression results of the impact of digital economy on agricultural green development in Table 4 are shown in Model 1. The regression coefficient of digital economy on agricultural green development is positive and significant at 5% confidence level, and hypothesis H1 is confirmed. This shows that the development of the digital economy helps to improve the green development 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 achieve the popularization of agricultural green production technology through technology demonstration effect and technology transfer effect, and thus enhance the green development of agriculture.

Table 4: Results of the baseline regression and mechanism analysis regression.

	(1)	(2)	(3)	(4)
	agtfp	agtfp	agtfp	agtfp
dig	0.042**	0.168***	0.172***	0.079***
	(0.020)	(0.047)	(0.042)	(0.022)
urban1	0.029	0.272**	0.266	0.069
	(0.022)	(0.119)	(0.244)	(0.070)
finan	0.009	-0.113**	-0.081	-0.006
	(0.016)	(0.051)	(0.054)	(0.016)
astruc	-0.010	0.144	0.111	0.005
	(0.016)	(0.099)	(0.100)	(0.014)
Indpw	-0.007	-0.008	-0.005	-0.023
	(0.014)	(0.066)	(0.066)	(0.017)
affir			-0.838**	
			(0.338)	
urban2				0.242*
				(0.143)
_cons	1.340***	1.672*	1.700	1.244***
	(0.205)	(0.993)	(1.135)	(0.146)
Control variables	Yes	Yes	Yes	Yes
Fixed effect	No	Yes	Yes	Yes
N	300	300	300	300
R2	0.267	0.589	0.384	0.283

Note: *, ** and *** indicate the significant level of 10%, 5% and 1%, respectively. The same below.

4.2 Robustness Test

The robustness test was carried out in the following three ways: 1) Change the explained variable. This study refers to Yin [19]'s accounting method on agricultural green development to replace the explained variables in order to verify the robustness of the baseline regression results. The regression results are shown in table5 column 1. 2) Endogeneity test. This study refers to the processing methods of Bai Peiwen et al. [20] and Li et al. [21], and selects the historical data of the number of fixed telephones and the number of post offices as instrumental variables for the development of the Internet. On the one hand, this data can effectively describe the level of regional communication development and meet the requirements of relevance; On the other hand, its influence on agricultural green production is weak, which satisfies the exclusivity hypothesis and is not related to the current disturbance term. Therefore, the historical data of the number of fixed telephones and the number of post offices basically meet the conditions of instrumental variable correlation and exogeneity. In order to ensure the validity of the estimated results, the control variables are added and the regression is carried out under the individual fixed effect model. Table5 column 2/3 and 4 are estimates under the three models when historical data on the number of landlines and the number of post offices are used as instrumental variables. From the perspective of the validity of instrumental variables, the coefficient of undiscernible test (Anderson LM) is 169.916 and the coefficient of weak instrumental variable test (C-D Wald F) is 422.685, both of which are significant at the 1% level, indicating that the hypothesis of insufficient identification of instrumental variables and weak instrumental variables are rejected. The Hansen test coefficient of 19.529 is significant at the 5% level, indicating that there is no over-recognition of instrumental variables. The results show that whether the explained variable is replaced or the explained variable is replaced, the impact of digital economy on the green development of agriculture is consistent with the previous estimated results, indicating that the endogenous problem is not enough to affect the conclusion of this study.

Table 5: Robustness test results

Variable	Agtfp new	2SLS	LIML	GMM
	(1)	(2)	(3)	(4)
	0.045*	0.182***	0.192***	0.136**
dig	(0.026)	(0.063)	(0.072)	(0.062)
	0.611	2.481***	2.511***	1.797***
_cons	(0.573)	(0.722)	(0.731)	(0.633)
Control variables	Control	Control	Control	Control
Individual fixed effects	Control	Control	Control	Control
N	300	225	225	225
R^2	0.230	0.139	0.131	0.121

4.3 Heterogeneity test

The impact of the digital economy on the green development of agriculture will also vary depending on the degree of government emphasis, natural environment characteristics and population density differences in different regions. In regions with a higher degree of attention, the government will promote the digital transformation of agriculture through a series of fiscal policies and tax policies, which will further accelerate the application of digital technology in the field of agricultural green production, and the impact of digital economy on the green development of agriculture in the region may be more obvious. For regions with different natural environmental characteristics, different land resources, environmental conditions and agricultural economic structure have their own characteristics, these greatly different planting methods and technologies will affect the level of agricultural green development, and the promotion effect of digital economy may also be different. In addition, diversified consumer demand, industrial structure and infrastructure will also have an impact on the relationship between the digital economy and the green development of agriculture.

Therefore, from the perspectives of policy, natural environment and population density [22], this study divided China into East - East - West - northeast, north and south sides of Qinling - Huai River Line and Hu line based on geographical location, and investigated the regional heterogeneity of the impact of digital economy on agricultural green development, as shown in Table 6. As can be seen from Table 6, the impact of digital economy on the green development of agriculture is significantly positive in the eastern region. The effect was less pronounced in the Midwest and Northeast. This is because the information infrastructure in the eastern region is relatively perfect, and the government's financial investment is relatively large. Therefore, the digital economy has promoted the digital transformation of the agricultural sector to a certain extent, and promoted the green development and growth of agriculture. The digital economy on both sides of the Qinling-Huaihe River Line has a promoting effect on the green development of agriculture, because the regions on both sides of the Qinling-Huaihe River line are in different climatic zones, and the main crops on both sides are also different. At the same time, there are great differences in agricultural production methods and overall agricultural industry construction planning on both sides. Under the background of the gradual rationalization of the flow of digital elements on both sides of the Qinling Mountains and Huaihe River, there is no obvious difference in the promotion effect of digital economy on the green development of agriculture. The digital economy has a significant positive impact on the agricultural green development in the southeast of the Hu Line, while the impact on the northwest of the Hu Line is not significant. The reason is that the population on the northwest side of the Hu Line is less than 5%, and the level of key factors such as labor force, market and industrial scale to promote the development of the digital economy is relatively low, and it is difficult to achieve the goal of agricultural green development only by expanding local digital infrastructure. The southeast region, which accounts for 95% of the population, has a larger market size, diversified consumer demand and a better infrastructure environment, which work together to promote the growth of green agricultural development.

Table 6: Estimation results of the impact of the digital economy on the agricultural green total factor productivity in different regions

Variable	Eastern region	Central and western regions	Northeast region	South of the "Qinling-Huaihe line	North of the "Qinling-Huaihe line	Southeast of the "Hu line”	Northwest of the "Hu line"
	0.137**	0.045	0.096	0.115**	0.319**	0.068*	0.118
dig	(0.068)	(0.053)	(0.093)	(0.045)	(0.136)	(0.040)	(0.100)
	3.101**	2.549*	3.594	2.053*	1.391	2.136**	5.198
_cons	(1.479)	(0.971)	(2.357)	(1.131)	(2.015)	(0.868)	(5.849)
Control variables	Control	Control	Control	Control	Control	Control	Control
Individual fixed effects	Control	Control	Control	Control	Control	Control	Control
N	110	80	110	190	110	200	100
R^2	0.189	0.257	0.135	0.171	0.214	0.148	0.199

5. Conclusions and suggestions

5.1 Conclusion

On the basis of using SBM model and GML index to measure agricultural green development, this study analyzed the impact of digital economy on agricultural green development 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 the impact of digital economy on agricultural green development 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 the green development of agriculture. 2) The enhancement effect of digital economy on agricultural green development presents significant heterogeneity in different regions. It is 0.137 in the eastern region, 0.115 and 0.319 on the north and south sides of the Qinling Mountains and Huaihe River, and 0.068 in the southeast of the Hu Line. This shows that the development of digital economy has promoted the promotion of green agricultural development in the eastern region, the northern and southern sides of the Qinling Mountains and Huaihe River, and the southeast side of the Hu Line.

5.2 Policy Suggestions

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 role of digital economy in promoting the green development of agriculture, we should further accelerate the development of digital economy, apply digital platforms and information technology to agricultural production, transform traditional agriculture with new technologies, and realize the coordinated development of digital technology and green agriculture through green production concept and green production level, so as to enhance the green development of agriculture. Second, the empirical results show that land intensive management efficiency has a significant intermediary effect in the process of digital economy affecting agricultural green development; After the efficiency of land intensive management exceeds a certain threshold value, the effect of digital economy on the green development of agriculture will be further improved. 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 the green development of agriculture. 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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