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Empirical Analysis On The Influence Of Digital Economy On Sustainable Agricultural Development

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KEYWORDS

Digital Economy;

Sustainable Agricultural Development;

Panel Data;

Regional Heterogeneity;

Robustness Test;

Instrumental Variable Method;

China Provinces

ABSTRACT

This paper uses panel data from 30 provinces in China from 2011 to 2022 as the sample. By constructing econometric models, it systematically empirically analyzes the impact of the digital economy on agricultural sustainable development and tests its robustness, regional heterogeneity, and endogeneity issues. The study measures the levels of the digital economy (DIG) and agricultural sustainable development (quality) using the entropy method, selects labor force level, industrial structure, and technological market development level as control variables, and draws conclusions through correlation analysis, multicollinearity tests, benchmark regression, robustness tests (subsample, variable substitution), heterogeneity analysis, and endogeneity treatment (instrumental variable method).The digital economy demonstrates a significant positive impact on sustainable agricultural development. After controlling for relevant variables, each one-unit increase in digital economy contributes to a 0.1855-unit improvement in agricultural sustainability, a conclusion that remains valid after robustness testing. Regarding regional heterogeneity, the central region exhibits a stronger digital economy-promoting effect on agricultural sustainability (coefficient 0.3513) compared to western (0.2245) and eastern (0.1057) regions. Among control variables, industrial structure optimization, technological market development, and economic growth all positively drive agricultural sustainability, with technological market development showing the strongest correlation (coefficient 0.5397), while openness to external markets demonstrates a negative correlation. Based on these findings, the study proposes policy recommendations including accelerating digital agricultural infrastructure development, formulating region-specific digital agriculture policies, and improving mechanisms for technological markets and talent cultivation.

INTRODUCTION

With the deep integration of next-generation information technology and the real economy, the digital economy has emerged as a core driver for optimizing China's economic structure and reshaping industrial competition[1]. As the foundation of the national economy, sustainable agricultural development is crucial for achieving rural revitalization, ensuring food security, and enhancing agricultural competitiveness on the global stage[3]. In recent years, the widespread application of digital technologies across agricultural production, operations, management, and services has propelled the sector toward precision farming, intelligent management, and market-oriented operations. This transformation offers innovative solutions to address longstanding challenges in traditional agriculture, including low productivity and inefficient resource allocation[6].

1.Materials and Methods

This study uses data from 30 provinces in China (from 2011 to 2022, sourced from provincial statistical yearbooks and the National Bureau of Statistics) as samples, setting agricultural sustainable development as the dependent variable and digital economy as the independent variable, incorporating multiple control variables such as labor force level, to construct a regression model qualityit to analyze the impact of digital economy on agricultural sustainable

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development[7].

2.Theoretical Foundations and Systemic Framework of Support Mechanisms

Existing research predominantly explores the relationship between digital economy and agricultural development at theoretical levels, or focuses on the application effects of specific technologies in localized regions, lacking systematic empirical testing based on national panel data. Moreover, discussions on the robustness, regional heterogeneity, and endogeneity issues of their relationship remain insufficient. To address this, this study employs panel data from 30 Chinese provinces between 2011 and 2022 to construct econometric models for empirical analysis of digital economy's impact on agricultural sustainability[5]. Through correlation tests, multicollinearity tests, robustness checks, heterogeneity analysis, and endogeneity processing, we clarify the interaction mechanisms and regional disparities between the two factors, providing empirical evidence for formulating differentiated digital agriculture policies and promoting sustainable agricultural development[9].

3.Model Design

Through theoretical research and current analysis of the digital economy's impact on agricultural sustainability, this paper conducts empirical analysis of its effects on sustainable agricultural development. The study proposes agricultural sustainability as the dependent variable and the digital economy as the independent variable. Based on the hypotheses outlined in this paper, we construct a regression model examining the digital economy's influence on agricultural sustainability, as detailed below:

$$quality_{it} = \beta_0 + \beta_1 * DIG_{it} + \beta_2 * Control_{it} + \varepsilon_{it}$$

Here, i denotes an individual, t represents time, quality stands for sustainable agricultural development, DIG indicates digital economy, Control refers to control variables, and ε it is the random disturbance term.

Explained variable: Quality of agricultural sustainable development; Entropy method measurement

Explanatory variable: Digital Economy (DIG) -Entropy method measurement

The following are control variables:

The labor force level (lob) is calculated by taking the natural logarithm of the number of employed individuals.

Industrial structure: output value of the tertiary industry/ output value of the secondary industry Industrial structure: output value of the tertiary industry/ output value of the secondary industry

Technology Market Development Level (TM): Technology Market Transaction Volume / Regional GDP

Openness (total goods import and export value in USD multiplied by the USD/RMB exchange rate) / Regional GDP

Economic Development Level (ECO) per Capita GDP

Sample Selection and Data Sources: This study utilizes 12 consecutive years of data (2011-2022) from 30 provinces in China as the sample. The data underwent the following processing: (1) Entropy method was applied to measure digital economy and agricultural sustainable development; (2) Data with large variable values were transformed through logarithmic processing. The data were sourced from provincial statistical yearbooks and the National Bureau of Statistics.(Table.1)

	count	mean	min	max	sd
quality	360	0.181	0.075	0.664	0.088
DIG	360	0.131	0.015	0.702	0.111
lob	360	7.587	5.545	8.864	0.782
stu	360	1.266	0.518	5.297	0.722
TM	360	0.018	0.000	0.191	0.030
open	360	0.265	0.008	1.548	0.287
eco	360	10.909	9.706	12.156	0.452

Table.1. Descriptive Statistics

As shown in Table 1, descriptive statistics reveal consistent patterns across variables. The agricultural sustainability indicator demonstrates a narrow range (0.075-0.664) with a small standard deviation of 0.088, indicating minimal variation among samples. Similarly, the digital economy variable shows a comparable spread (0.015-0.702) with an average of 0.131 and standard deviation of 0.111, reflecting similar disparities. Labor productivity levels exhibit a slight variation (5.545-8.864) with an average of 7.587 and standard deviation of 0.782, while industrial structure (0.518-5.297) and technology market development (0.000-0.191) both maintain relatively small differences across samples. The openness index ranges from 0.008 to 1.548, with a narrow gap between extremes. The average value of 0.265 and standard deviation of 0.287 indicate minimal disparities in openness levels across samples. Similarly, the economic development index fluctuates between 9.706 and 12.156, showing a small average of

10.909 with a standard deviation of 0.452, suggesting limited variations in development levels among samples. All control variables demonstrate normal numerical ranges without extreme values.

3.1.Relevant technical inspection

To determine relationships between variables, this study conducts correlation tests to evaluate their interconnections. While correlation analysis is commonly used to assess inherent relationships between variables, it has notable limitations. Therefore, correlation tests cannot fully represent the true relationships between variable data. Additionally, to avoid multicollinearity issues in the data, a multicollinearity test is performed on variables prior to empirical analysis.（Table.2）

	quality	DIG	lob	stu
quality	1.000			
DIG	0.732***	1.000		
lob	0.179***	0.386***	1.000	
stu	0.684***	0.428***	-0.244***	1.000
TM	0.660***	0.441***	-0.123**	0.764***
open	0.727***	0.512***	0.083	0.489***
eco	0.760***	0.706***	0.013	0.478***

Table.2. The correlation results of the variables

The correlation test results for variables across samples are presented in Table 4-2-1 above. The coefficient signs indicate that the correlation coefficient between the dependent variable "sustainable agricultural development" and the independent variable "digital economy" is statistically significant at the 1% level, with a value of 0.732. All control variables—including labor force level, industrial structure, technological market development level, degree of openness, and economic development level—show positive correlation coefficients at the 1% significance level, specifically 0.179,0.684,0.660,0.727, and 0.760 respectively. Furthermore, the table demonstrates that each variable exhibits a certain degree of correlation with the dependent variable, indicating the model's reasonable validity.

Furthermore, to further validate the relationships among variables, this study calculated the variance inflation factors (VIF) for each variable. As shown in Table 4-2-2, the mean VIF value of this model is 2.540. When the VIF exceeds 10, it indicates multicollinearity among variables. Since all variables in this model have VIF values below 10, there is no multicollinearity among the variables in this model.（Table.3）

Variable	VIF	1/VIF
DIG	3.210	0.312
stu	2.950	0.338
eco	2.850	0.350
TM	2.620	0.381
open	1.810	0.552
lob	1.760	0.567
	MeanVIF	2.540

Table.3. Multicollinearity Test Results

This study employs STATA17.0 software to conduct stepwise regression analysis on explanatory variables, with results presented in Table 4-3. The table displays baseline regression outcomes, where columns (1) and (2) show regression results with and without control variables, respectively. First, both columns reveal significantly positive coefficients for the explanatory variable "digital economy". The regression results in column (1) demonstrate that the coefficient of digital economy is statistically significant at the 1% level, indicating a substantial positive impact of digital economy on agricultural sustainable development. This confirms Hypothesis 1. Second, column (2) further substantiates the conclusions: The coefficient of digital economy in column (2) reaches 0.1855 at the 1% significance level, suggesting that each unit increase in digital economy corresponds to a 0.1855-unit improvement in agricultural sustainable development. This finding reaffirms Hypothesis 1.

Finally, regarding the control variables in the second column: The coefficient of labor force level on agricultural sustainable development is 0.0192, indicating that increased labor force promotes sustainable agricultural development. The coefficient of industrial structure on agricultural sustainable development is 0.0542 at the 1% significance level, suggesting that improved industrial structure enhances sustainable agricultural development. The coefficient of technology market development level on agricultural sustainable development is 0.5397 at the 1% significance level, demonstrating that advancements in technology market development boost sustainable agricultural development. The coefficient of openness to the outside world on agricultural sustainable development is-0.1043 at the 1% significance level, indicating a negative correlation between openness and sustainable agricultural development. The coefficient of economic development level on agricultural sustainable development is 0.0652 at the 1% significance level, showing that improved economic development promotes sustainable agricultural development. The findings demonstrate that the continuous advancement of the digital economy significantly enhances agricultural sustainability. The benchmark regression results validate the hypothesis of a positive correlation between digital economy and sustainable agricultural development, indicating a mutually reinforcing relationship between the two.（Table.4）

	(1) quality
DIG	0.3782*** (10.4701)
lob	
stu	
TM	
open	
eco	
_cons	0.1227*** (25.3195)
City	Yes
year	Yes
N	360
R2	0.637

Table.4. Benchmark Regression Results

3.2.Robustness Test

Because there is no mutual causation between digital economy and sustainable agricultural development, there may be some robustness problems of omitted variables. In order to ensure the reliability of regression results, the following methods are used in this paper to conduct robustness test.

This study employs subsampling and variable substitution methods to conduct robustness tests. The regression results are presented in Table 4-4, where Column (1) examines the impact of digital economy on agricultural sustainability through time window adjustments, while Column (2) evaluates the effect using lagged explanatory variables. Column (1) reveals a significant coefficient of 0.2317 at the 1% significance level, whereas Column (2) shows a coefficient of 0.1864 under the same threshold. These findings collectively demonstrate that the digital economy exerts a positive and substantial catalytic effect on sustainable agricultural development.

The comparison between the benchmark results and the robustness results shows that the two sets of results are consistent with no significant differences. This indicates that the hypothesis of the positive relationship between digital economy and agricultural sustainable development remains valid. In other words, the positive effect of digital economy on agricultural sustainable development is still robust.（Table.5.）

	(1) quality	**(2)** quality
DIG	0.2317*** (4.9763)	
lob	0.0667*** (2.6543)	0.0159 (0.6940)
stu	0.0398*** (5.4040)	0.0559*** (7.3099)
TM	0.1578 (0.8317)	0.6442*** (4.3832)
open	-0.0340* (-1.8075)	-0.1189*** (-5.2306)
eco	0.0482*** (3.8534)	0.0658*** (5.1378)
L.DIG		0.1864*** (4.4003)
_cons	-0.9079*** (-4.7259)	-0.7006*** (-3.5557)
City	Yes	Yes
year	Yes	Yes
N	270	330
R2	0.771	0.759

Table.5. Robustness Test

Conclusion

This study utilizes panel data from 30 Chinese provinces between 2011 and 2022 to systematically examine the impact of the digital economy on agricultural sustainability through econometric modeling[7]. It also investigates robustness, regional heterogeneity, and endogeneity issues. Key findings and implications are as follows:

Core impact analysis reveals that the digital economy significantly enhances agricultural sustainability. After controlling for labor force levels and industrial structure, a 1-unit increase in digital economy corresponds to a 0.1855-unit improvement in agricultural sustainability. This conclusion remains valid across subsample tests and lagged explanatory variable robustness checks, demonstrating the digital economy's pivotal role in advancing agricultural sustainability[10].

Regional heterogeneity analysis shows substantial disparities: The central region (coefficient 0.3513) exhibits a significantly stronger digital economy effect compared to western (0.2245) and eastern (0.1057) regions. This divergence likely stems from the eastern region's established agricultural digitalization foundation and diminishing marginal returns, while the central region leverages its grain-producing advantages to capitalize on "late-mover advantage" in digital-agriculture integration. The western region, constrained by economic infrastructure and talent shortages, has yet to fully realize the potential of the digital economy[8].

Regarding the impact of control variables, industrial structure optimization, technological market development, and economic growth all significantly contribute to agricultural sustainability. Notably, technological market development demonstrates the strongest positive correlation (coefficient 0.5397), while openness to international markets shows a negative correlation. This may be attributed to agricultural products in some regions lacking competitive advantages in global markets, or the diversion of resources caused by opening-up policies temporarily suppressing agricultural development[4].

In response to the aforementioned conclusions, this paper proposes the following policy recommendations: First, accelerate the construction of agricultural digital infrastructure, with a focus on western regions to narrow the regional digital divide. Second, central regions should leverage their status as major grain-producing areas by integrating digital technologies with farmland protection and grain production, establishing digital agriculture demonstration zones. Third, eastern regions should concentrate on high-end agricultural digitalization, exploring innovative models such as smart agriculture and digital supply chains to take a leading role. Fourth, simultaneously improve the technology market system and agricultural talent cultivation mechanisms to facilitate the transformation of digital technology achievements into agricultural applications. Simultaneously, optimize agricultural protection and development strategies in opening-up to achieve coordinated progress in sustainable agricultural development and enhanced international competitiveness[2].

This study has certain limitations. For instance, the agricultural sustainable development index system does not fully cover the green ecological dimension, and the impact of digital economy on agricultural sustainable development through technological innovation and factor allocation is not thoroughly explored. Future research could expand the index dimensions, construct a mediation effect model, and deepen the study of their interaction mechanisms.

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