An Empirical Analysis of High-Quality Agricultural Development in Anhui Province Driven by the Digital Economy

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Abstract: The digital economy has become a key driver of high-quality agricultural development. Based on the theoretical analysis, an empirical model covering indicators for both was built to explore the effect of the digital economy on the high-quality development of agriculture in Anhui Province. Findings show the digital economy boosts agricultural productivity and high-quality development by enhancing agricultural productivity, especially in central Anhui. To improve this effect, integrating the digital economy with agriculture is recommended to address regional disparities.

Keywords: Digital Economy; High-Quality Agricultural Development; Agricultural Productivity; Anhui Province

1. Introduction

As a major agricultural country, China views agriculture as a foundational industry for national economic construction and development. The central government's "No. 1 Document" emphasizes the strategy of comprehensively promoting the revitalization. It can accelerate the modernization of agriculture and rural areas and promote the construction of modernization with Chinese characteristics. It is a reflection of the importance China attaches to agriculture. Additionally, the "China Digital Economy Development Research Report (2024)" notes a 10.78% digital economy penetration rate in the primary sector in 2023, up 0.32% from the prior year. This figure indicates its growing role in agriculture. Thus, studying the digital economy is vital for fostering high-quality agricultural advancement.

Anhui, a major agricultural province in China, achieved a grain output of 40 million mu in 2023, ranking fifth nationwide. To accelerate agricultural digital transformation, Anhui issued the "Action Plan for Accelerating the High-Quality Development of the Digital Economy (2024-2026)," proposing the construction of "Digital Anhui Agriculture." However, challenges like weak digital infrastructure and technology gaps remain. This study proposes suggestions to use the digital economy for high-quality agricultural development in Anhui, advancing its digital transformation thereby.

Recent studies have explored the relationship between the digital economy and agricultural development from various perspectives. Li Yan et al.[1] (2024) found that the digital economy improves agricultural production efficiency under carbon emission constraints, in favor of high-quality agricultural development. Wu Zhencai[2] (2024) demonstrated the digital economy's significant role in boosting the international trade of agricultural products in the local and surrounding areas. Yan Xin et al.[3](2024) highlighted the digital economy's ability to drive rural industrial upgrading, enhance household endowments, and accelerate agricultural modernization. Ding Yulong et al.[4](2024) showed that the digital economy directly and indirectly advances rural modernization through technological innovation. Cheng Miaomiao et al.[5](2024) proposed strategies for integrating the digital economy with rural ecotourism to promote rural revitalization.

Current research inadequately explores how the digital economy drives high-quality agricultural development, particularly regarding conceptual definitions, measurement indicators, and modeling frameworks. Focusing on Anhui Province, this study empirically examines the impact pathways and mechanisms of the digital economy on agricultural development using descriptive analysis and regression testing,

and so on, while providing corresponding recommendations.

2.Theoretical Analysis and Research Hypotheses

2.1 Digital Economy's Direct Impact on Anhui's High-Quality Agricultural Development

Digital infrastructure promotes Anhui's high-quality agricultural development. Digital infrastructure drives Anhui's agricultural development by enabling data sharing through digital platforms and databases. It can also use IoT and AI technologies to optimize resource allocation, improving efficiency while reducing waste to maximize productivity.

Create a digital industry that promotes Anhui's high-quality agricultural development. Develop a digital agriculture industry to expand Anhui's market reach globally, increasing sales and farmer incomes. Digital technologies minimize spoilage, enhance value-added processing, and optimize agricultural supply chains.

The digital innovation potential significantly enhances agricultural development in Anhui Province by promoting mechanization and intelligent farming. It can reduce labor costs and improve production efficiency. The advancement of digital technologies also simplifies operational procedures. Farmers can better accept them. This process simultaneously elevates farmers' digital literacy and fosters professional skill development, ultimately driving high-quality agricultural transformation.

Therefore, this study posits Hypothesis 1: The digital economy positively drives Anhui's high-quality agricultural development.

2.2 Digital Economy's Indirect Impact on Anhui's High-Quailty Agricultural Development

The digital economy precisely manages crop growth by utilizing IoT sensors to monitor soil and water conditions and enables data-driven irrigation and fertilization decisions. The integration of robotics and remote sensing reduces labor requirements while improving resource allocation and pest management, ultimately increasing both crop yields and quality.

The digital economy enables integrated development across the entire agricultural supply chain by facilitating closer collaboration between upstream and downstream partners and implementing product traceability systems. It can achieve real-time production monitoring and value-added consumer experiences. The digital economy improves product quality, strengthens consumer confidence, and maximizes overall supply chain value.

The digital economy can promote the formation of customized and personalized agricultural production models. It enables customized agricultural production through AI-optimized crop selection to enhance yields. It also allows demand-based data analysis to minimize land loss, facilitate personalized farming, and monitor crop growth in real-time to enhance consumer engagement and satisfaction.

Consequently, this study propose: Hypothesis 2: The digital economy indirectly enhances Anhui's high-quality agricultural development by increasing productivity.

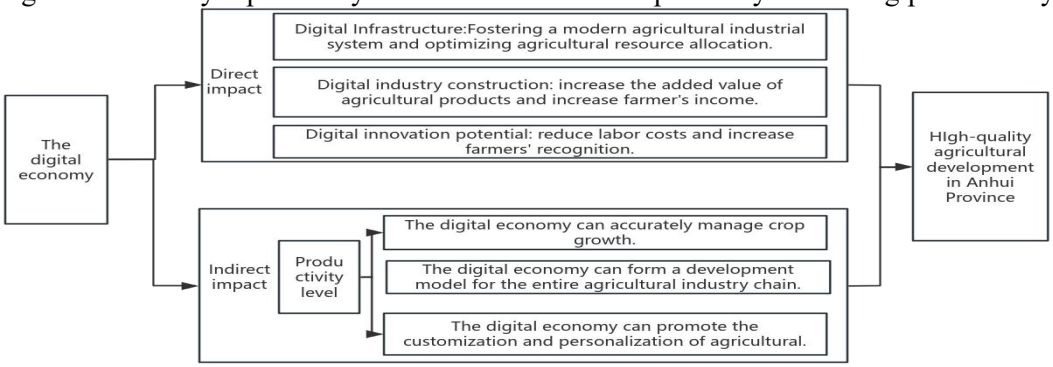

Figure 1. Research Framework for the Digital Economy Driving Anhui's High-Quality Agricultural Development

3. Research and Design

3.1 Model Setting

To examine how the digital economy drives high-quality agricultural development in Anhui Province, this study draws on the benchmark regression models of Wen Ruobing[6] (2024) and Li Ling [7](2024) to construct the following model.

$$Y_{it} = a_0 + a_1 X_{it} + a_2 Z_{it} + \mu_i + \sigma_t + E_{it} \quad (1)$$

In Equation (1), Y_{it} measures the agricultural high-quality development level of city i in year t. X_{it} captures the corresponding digital economy development level. The control variables Z_{it} incorporates factors including economic development, transportation infrastructure, education investment, and urbanization level. To account for the effects brought about by the individual differences and the changes in time, the model includes individual fixed effects (μ_i) and time fixed effects (σ_t), with E_{it} representing the random disturbance term.

To examine how the digital economy enhances agricultural quality development in Anhui Province through production efficiency, we adopt Li Ling's[7](2024) mediation effect model as follows:

$$pro_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \mu_i + \sigma_t + E_{it} \quad (2)$$

$$Y_{it} = r_0 + r_1 X_{it} + r_2 pro_{it} + r_3 Z_{it} + \mu_i + \sigma_t + E_{it} \quad (3)$$

In Equation (2), pro_{it} represents the agricultural productivity level of city i in year t, serving as the mediating variable.

3.2 Variable Selection

3.2.1Dependent variable:Agricultural development quality (Yit)

This paper measures agricultural development quality in Anhui Province through six dimensions: production modernization, industrial efficiency, green production, social benefits, infrastructure, and land governance. Using the entropy method, we construct a comprehensive index (Y_{it}) from six secondary and 11 tertiary indicators (Table 1) as our dependent variable.

Table 1. Agricultural High-Quality Development Evaluation Indicators

Level 1	Level 2	Level 3	Measurement	Attribute
High-quality agricultural development level	modernization Production	Labor Productivity	Agricultural output / Primary industry workers	Positive
		Mechanization Degree	Total agricultural machinery power	Positive
		Irrigation Coverage	Effective irrigated area	Positive
	Industrial Benefits	Total Output Value	Gross agricultural output value	Positive
	Green Production	Fertilizer Use Per Unit Area	Fertilizer applied / Sown area	Negative
	Social Benefits	Disposable Income Per Farmer	Per capita farmer income	Positive
		Consumption Expenditure Per Farmer	Per capita farmer spending	Positive
	Infrastructure	Rural Electricity Consumption	Total rural electricity usage	Positive
		Total Reservoir Capacity	Total reservoir capacity	Positive
	Land Goverance	Waterlogging Control Area	Waterlogging control area	Positive
		Soil Erosion Control Area	Soil erosion control area	Positive

3.2.2Independent variable: Digital economy development level (Xit)

Following Yu Jiahua[9](2024) and Hou Yi[10](2024), this paper measures the digital economy development level (X_{it}) in Anhui Province through three dimensions: digital infrastructure, industrial foundation, and innovation potential. We construct a comprehensive index using 10 tertiary indicators (Table 2), weighted by the entropy method.

Table 2. Digital Economy Evaluation System

Level 1	Level 2	Level 3	Measurement	Attribute
Digital Economy Development Level	Digital Infrastructure	Internet Penetration Rate	Number of broadband ports	Positive
		Mobile Phone Penetration Rate	Mobile phone adoption rate	Positive
		Communication Infrastructure	Length of long-distance optical cables	Positive
		Base Station Construction	Number of mobile base stations	Positive
	Digital Industry Base	Digital Industry Output	Per capita telecom business volume	Positive
		Digital Industry Applications	Per capita express delivery	Positive

			revenue	
		Digital Industry Revenue	E-commerce sales volume	Positive
	Digital Innovation Potential	R&D Investment	R&D funds of industrial enterprises	Positive
		Market Scale&Research Capability	Technology market transaction volume	Positive
		Research Capability	Number of patent applications granted	Positive

3.2.3 Control variables (Zit)

Following Wu Zhencai[2] (2024), we include four control variables: (1) economic development (per capita GDP); (2) transportation infrastructure (freight turnover); (3) education investment (education expenditure); and (4) urbanization level (urban population share).

3.2.4 Mediating variable:Agricultural total factor productivity (proit)

Adopting Xu Jian et al.'s[11](2008) approach, we measure agricultural productivity using DEA-calculated total factor productivity across Anhui's 16 prefecture-level cities.

Table 3. Selected Variables

Variable type	Symbol	Variable Name	Measurement/Description
Dependent Variables	Y_{it}	High-Quality Agriculture Development	Factor analysis composite score
Independent Variables	X_{it}	Digital Economy Developement	Factor analysis composite score
Control Variables(Z_{it})	GDP_{it}	Economic Development	GDP per capita
	TR_{it}	Transportation Infrastructure	Freight turnover
	ED_{it}	Education Investment	Education expenditure
	UR_{it}	Urbanization Rate	Urban population share

3.3 Data sources and Processing

3.3.1 Data sources

This study utilizes panel data from Anhui Province's cities and counties (2013-2023). The data is from the National Bureau of Statistics, Anhui Statistical Yearbook, and government department releases. This paper uses patent application data from the Anhui Intellectual Property Research Center to exclude partial data and address it through interpolation.

3.3.2 Data Processing

This study constructs indicator systems for the digital economy and agricultural development. It standardizes indicators across varying statistical measures by data preprocessing. This study also employs Wang Juanjuan et al.'s[8](2021) method to address data heterogeneity across regions. Indicators are classified as positive (e.g., Internet penetration rate) or negative (e.g., fertilizer use per unit area) based on their directional impact on evaluation outcomes.

4.Empirical Analysis

4.1 Descriptive Statistical Analysis

Descriptive statistics reveal significant regional disparities in Anhui Province (2013-2023): the agricultural development level (mean=23.860, range up to 236.257) and digital economy development (mean=0.051, SD=0.021) both show substantial variation, and they indicatae an imbalance between the agricultural development level and digital economy development. Economic development indicators (SD=0.776, range 0.360-4.092) mean that the sample selected is richer and there are significant differences in the level of economy between cities and counties. There are large gaps in transportation infrastructure, education investment, and urbanization levels.

Table 4. Descriptive Statistics of Key Variables

Variable	Number of samples	Mean	Std. Dev.	Min	Max
Y_{it}	176	23.860	22.904	9.554	236.257
X_{it}	176	0.051	0.021	0.007	0.085
GDP_{it}	176	0.346	0.776	0.360	4.092
TR_{it}	176	0.059	0.016	0.297	0.850
ED_{it}	176	0.019	0.027	0.006	0.164
UR_{it}	176	18.977	5.353	0.220	34.052

4.2 Benchmark Regression Analysis

Table 5 shows that the digital economy in Anhui Province significantly promotes high-quality agricultural development, with a positive effect at the 1% level.

Column (1) presents the direct relationship between the dependent and independent variables. Columns (2) through (5) demonstrate how this relationship evolves with the sequential addition of control variables. The regression results show that, whether control variables are included or not, the digital economy in Anhui Province has a significantly positive impact on high-quality agricultural development at the 1% level, with stable coefficients. This supports Hypothesis 1, preliminarily confirming that the digital economy directly promotes high-quality agricultural development in Anhui Province.

To ensure model reliability, all variables were log-standardized to eliminate heteroscedasticity. Unit root tests confirmed stationarity ($p < 0.05$ for all variables), further supporting Hypothesis 1 that the digital economy directly promotes high-quality agricultural development in Anhui Province.

Table 5. Benchmark Regression Analysis

variant			Y_t		
	(1)	(2)	(3)	(4)	(5)
X_t	0. 1129554***	0. 1107482**	0. 1085884***	0. 1052014*	0. 1733979***
	(0.332)	(0.310)	(0.120)	(0.313)	(0.0257)
GDP_t	0.00955539*	0.0711092*	0.1094374*	0.1263418*	0.2504129***
	(0.0004335)	0.0167493	0.01434598*	(0.00452)	(0.000557)
TR_t			0.177*	0.155*	0.136
			(0.0383)	(0.0732)	(0.0650)
ED_t				0.0135*(0.00327)	0.0165*(0.00535)
UR_t					0.300(0.193)
constant term	-0.00353	-0.0225	-0.0812*	-0.369*	-765**
	(0.0557)	(0.0369)	(0.0335)	(0.512)	(0.285)
Individual Fixed		YES	YES	YES	YES
Time-point fixed	YES	YES	YES	YES	YES
Observed value	120	120	120	120	120
R2	0.182	0.128	0.183	0.113	0.434

Note1: ***, **, and * denote significance at 1%, 5%, and 10% levels respectively; standard errors in parentheses.

Table 6. Results of the Stability Test

variant	t-statistic	p-value
X_{it}	-9.028***	0.0000
GDP_{it}	-13.5721	0.0000
TR_{it}	-9.7082	0.0000
ED_{it}	-8.4753	0.0000
UR_{it}	-19.9728	0.0000

4.3 Robustness Tests

To ensure result reliability, we follow Xie Wei et al. [12](2022) to verify stability by (1) shortening the time horizon and (2) removing outliers.

4.3.1 Shortening time

Using 2015-2022 data (excluding impacts resulting from the enactment of relevant policies after 2023), the digital economy's coefficient remains significantly positive (Table 7, Model 1), confirming result stability.

4.3.2 Outlier Removal

After excluding incomplete data observations, the digital economy maintains a significantly positive coefficient (Table 7, Model 2). It confirms the model's robustness. Both robustness tests support the finding that digital economy development directly promotes Anhui's agricultural quality improvement.

Table 7. Robustness Test Result

variant	Shortening time	Outlier Removal
X_{it}	0.4698***	0.4372**
	(0.0351)	(0.0845)
GDP_{it}	0. 1024684***	0. 1717157***
	(0.00799)	(0.000215)
TR_{it}	0.2061791***	0. 1123485*
	(0.0169)	(0.0.8740366)
ED_{it}	2.656564***	0.3634926***

	(0.000333)	(0.00321)
UR_{it}	-0.2928532*	-0.451989*
	(0.00916)	(0.0637)

Note2: ***, **, and * denote significance at 1%, 5%, and 10% levels respectively; standard errors in parentheses.

4.4 Mediation Analysis

To examine whether the digital economy indirectly promotes agricultural development through productivity improvements, we conduct mediation analysis (results in Table 8).

Model (1) includes core and control variables. Model (2) adds agricultural productivity as the mediator. It shows the digital economy significantly improves productivity (1% level). Model (3) confirms both the digital economy and productivity positively enhance agricultural development (1% significance).

The mediation analysis reveals a partial mediation effect: when agricultural productivity is introduced as a mediator, the coefficient of the digital economy decreases from 0.9179 to 0.8619 while remaining significant. It demonstrates that the digital economy promotes high-quality agricultural development through enhancing productivity indirectly, thereby confirming Hypothesis 2.

Table 8 Analysis Results of Mediation Effect

variant	(1)Yt	(2)pro	(3)Yt
X_{it}	0.9179*** (0.0845)	0.9728*** (0.0828)	0.8619*** (0.00799)
pro_{it}			0.0575** (0.000215)
GDP_{it}	0.0109	0.0721	0.0067
	(0.000202)	(0.000333)	(0.00321)
TR_{it}	0.0492**	0.1546***	0.0403**
	(0.00379)	(0.00916)	(0.000640)
ED_{it}	0.7760*** (0.000779)	1.1136* (0.00540)	0.7119*** (0.00845)
UR_{it}	0.0409	-0.1107	0.0473
	(0.0259)	(0.0970)	(0.216)
Observed value	120	120	120
R^2	0.9494	0.3018	0.9512

Note3: ***, **, and * denote significance at 1%, 5%, and 10% levels respectively; standard errors in parentheses.

4.5 Heterogeneity Analysis

Considering regional disparities in digital economy development, we conduct a geographic heterogeneity analysis by dividing Anhui Province into southern, central, and northern sub-regions. The results (Table 9) demonstrate significant variations in the digital economy's impact on agricultural development across these regions, with the strongest effects observed in central Anhui (including Hefei and Lu'an), followed by southern (Huangshan, Wuhu) and northern areas (Huaibei, Bozhou), reflecting distinct regional development patterns.

The study reveals significant regional heterogeneity in the digital economy's impact on agricultural development (all coefficients significant at the 1% level): Central Anhui shows the strongest effect (0.97). It benefits from advanced digital infrastructure (e.g., Smart Computing Center) and regional synergy. Southern Anhui is second (0.92), indicating rapid digital growth. Northern Anhui trails (0.86) due to inadequate digital infrastructure and talent shortages. These findings demonstrate that the digital economy's agricultural benefits intensify with regional digital advancement levels.

Table 9. Heterogeneity Analysis

Variable	Southern Anhui	Central Anhui	Northern Anhui
Xit	0.9179***	0.9728***	0.8619***
	(0.01391)	(0.03229)	(0.01481)
GDPit	-0.0511817	0. 1664546**	0.2881996***

	(0.0197)	(0.00381)	(0.0144)
TRit	0.3365653***	0. 1800308*	-0.0701487
	(0.0189)	(0.0508)	(0.0117)
EDit	0.0977623	-0.2293815*	-0.3373062***
	(0.0120)	(0.0690)	(0.250)
URit	-0.0670313	-0. 1011204**	- 0.223458***
	(0.0581)	(0.0336)	(0.0759)
cons _	-1. 163545*	-0.1084556	1.80101*
	(0.00375)	(0.0207)	(0.0191)

Note4:***, **, * denote significance at 1%, 5%, 10% levels (Stock-Yogo test); standard errors in parentheses

5.Conclusions and Recommendations

5.1 Conclusions

This study analyzes Anhui Province's 2013-2023 panel data to investigate the digital economy's role in promoting high-quality agricultural development. The key findings reveal: (1) through descriptive statistical analysis, all regions of Anhui are uneven in the indicators studied in this paper; (2) the conclusion that the digital economy's direct positive impact on Anhui's agricultural development is reliable (validated by robustness checks); (3) the mechanism that the digital economy indirectly contributes to the high quality of agriculture by raising the level of productivity is established; and (4) stronger effects in digitally advanced regions, demonstrating clear regional heterogeneity. These results highlight the importance of addressing regional imbalances while leveraging digital technologies to enhance agricultural productivity and development.

5.2 Recommendations

To promote high-quality agricultural development in Anhui Province, we recommend (1) Anhui strengthen digital infrastructure in underdeveloped regions to reduce regional disparities and (2) Anhui accelerate "Digital Anhui Agriculture" through IoT and big data applications. It can try to deepen the integration of the digital economy with agriculture and cultivate digital-agriculture talent; (3) Anhui should introduce more policies to support the construction of digital agriculture to improve agricultural productivity in order to promote Anhui's agriculture; (4) Anhui can strengthen exchanges and co-operation between developed regions of the digital economy and regions lagging behind in the digital economy to promote the high-quality development of agriculture in regions lagging behind in the digital economy; (5) Anhui should actively cultivate agricultural product brands with regional characteristics by the digital means to increase sales of agricultural products; (6) In order to increase farmer's income, we should improve the construction of agricultural e-commerce platforms and enhance the operational efficiency of rural e-commerce;and (7) Anhui Province can increase investment in agricultural technology innovation and data-sharing platforms to build agricultural data analysis and technical support for new agricultural entrepreneurs. These measures will facilitate digital transformation and boost agricultural productivity across the province.

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