

Digital Empowerment of Agricultural and Rural Modernization Promoting Comprehensive Rural Revitalization in Suzhou

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Abstract: Digital technology, deeply embedded in the entire process of agricultural and rural development, has become a key driving force for comprehensive rural revitalization. This study focuses on Suzhou City in Anhui Province and empirically examines the influence, transmission mechanisms, and threshold characteristics of digital empowerment on the modernization of agriculture and rural areas as well as rural revitalization. The analysis employs an enhanced entropy weight-TOPSIS approach, mediation effect model, and threshold regression model, utilizing panel data from 2023 to 2025. The findings reveal that digital empowerment has a substantial positive impact on the agricultural and rural modernization of Suzhou, with key transmission channels identified as industrial integration (28.7%), factor mobility (24.1%), and inclusive public services (21.3%). Moreover, the empowerment effect displays a dual threshold linked to digital infrastructure, where the coefficient increases significantly from 0.142 to 0.486 upon surpassing the second threshold. Facing practical bottlenecks such as unbalanced county-level development and shortage of digital talents, Suzhou needs to make precise efforts from three dimensions: strengthening digital infrastructure, cultivating digital farmers and deepening industrial integration, providing a path reference for digital-empowered rural revitalization in northern Anhui's major agricultural cities.

Keywords: Digital Empowerment; Agricultural and Rural Modernization; Rural Revitalization; Mediation Effect; Threshold Effect

1. Introduction

The rapid iteration and deep integration of digital technology are reshaping the underlying

logic and driving mechanisms of agricultural and rural development. In 2025, the state explicitly proposed "to promote the concentration of advanced production factors through technological innovation and develop new agricultural productive forces tailored to local conditions." Digital empowerment has become the core pathway to advancing agricultural and rural modernization and achieving comprehensive rural revitalization.

Suzhou, a key agricultural city located in northern Anhui and a significant hub for grain production, boasts more than 9 million mu of arable land. The city's annual output of grain, fruits, vegetables, meat, eggs, and milk surpasses 23.42 billion jin. In 2024, the contribution rate of advancements in agricultural science and technology reached 67.86%, reflecting the city's phased accomplishments in digital agriculture and rural e-commerce. A number of application scenarios such as smart planting, precision breeding and digital agricultural demonstration bases have been implemented one after another, and the model of 'e-commerce + characteristic agriculture' has driven the rapid growth of rural online retail sales, providing a solid foundation and realistic conditions for digital empowerment. However, Suzhou's comprehensive index of agricultural and rural modernization remains in the lower-middle range, with significant county-level disparities. The urban-rural digital divide, the shortage of digital compound talents and the insufficient depth of industrial integration still constrain the release of digital empowerment potential, indicating that the transformation from digital applications in isolated points to systematic empowerment remains to be realized. Previous research predominantly examines the provincial or national levels, showing a deficiency in micro-empirical analysis in major agricultural cities, as well as a limited investigation into the nonlinear characteristics and regional adaptability of the effects of digital empowerment. In particular, the threshold

conditions (such as digital infrastructure level and human capital stock) for digital empowerment to take effect in agricultural regions have not been systematically identified, which weakens the precision of policy recommendations. Drawing from the practices observed in Suzhou, this paper develops a framework consisting of "theoretical mechanism - empirical test - policy optimization" to comprehensively analyze the impacts, pathways, and prerequisites of digital empowerment on the modernization of agriculture and rural areas. The goal is to address regional research deficiencies and offer replicable insights for regions like Suzhou, northern Anhui, and other comparable agricultural areas nationwide.

2. Literature Review and Mechanism Analysis

2.1 Research Progress on Digital Empowerment of Agricultural and Rural Development

The empowerment effect of digital technology on agriculture and rural areas has accumulated rich research. From the research lineage, the relevant literature has experienced a development from agricultural informatization to smart agriculture and then to digital rural construction, and the research object has expanded from a single production link to the whole chain of agricultural and rural development. On the agricultural production side, technologies such as the Internet of Things, big data and artificial intelligence have significantly improved agricultural production efficiency and resource utilization through precise monitoring and intelligent decision-making. Studies show that after digital transformation, agricultural management and protection costs decrease by about 10% on average, and per-mu benefits increase by more than 20%. On the circulation side, digital platforms have effectively broken the spatiotemporal barriers of agricultural product circulation, promoted the docking of smallholder farmers with the large market, and broadened channels for farmers to increase income [1]. On the service side, digital technology facilitates the transfer of high-quality educational, medical, and financial resources to rural regions, thereby progressively reducing the disparity in public services between urban and rural areas [2]. It can be seen that research on digital empowerment has gradually expanded

from a single production link to the whole chain of agricultural and rural development.

Concerning the mechanism of empowerment, experts mostly agree that the three fundamental pathways are the integration of industries, the mobility of factors, and the provision of inclusive services. A configurational analysis based on fsQCA and NCA shows that the digital economy can empower agricultural and rural modernization through multiple pathways—such as informatization-led, digital-industry-dominated, and mobile-internet-driven pathways—exhibiting a clear characteristic of "equifinality" [3]. Industrial integration highlights that digital technology dissolves the industrial divide between urban and rural areas, facilitating the cohesive growth of agriculture, processing, and services. Factor mobility focuses on digital platforms attracting capital, talents and other factors back to rural areas and optimizing resource allocation; inclusive services focuses on digital technology promoting the sinking of public services such as education and medical care. However, existing studies pay insufficient attention to differentiated empowerment paths at the level of major agricultural cities, and the threshold characteristics of digital empowerment effects, such as digital infrastructure level and human capital stock, have not been systematically identified. Most threshold studies use national or provincial data, and their conclusions have limited applicability to agricultural prefecture-level cities, leaving room for regional refinement. Furthermore, the majority of current research relies on cross-sectional or brief panel datasets, which poses challenges in accurately capturing the dynamic progression of empowerment effects. Additionally, there remains a lack of systematic identification regarding threshold conditions within agricultural areas. Utilizing county-level panel data from Suzhou, this paper aims to address these gaps.

2.2 Theoretical Mechanism and Research Hypotheses

The core logic of digital empowerment of agricultural and rural modernization lies in: taking digital technology as the medium, driving the systematic transformation of agricultural production methods, industrial forms and governance models through three mechanisms of efficiency improvement, structural optimization and governance improvement, thereby realizing

the comprehensive promotion of agricultural efficiency, rural prosperity and farmers' income growth.

First, the efficiency improvement mechanism. Digital technology optimizes the entire agricultural production process through precise perception, intelligent decision-making and automatic control, realizing the shift from experience-based production to data-driven production. At the same time, digital technology improves agricultural total factor productivity by optimizing factor allocation and reducing information asymmetry, which constitutes the most fundamental empowerment path. For example, the integration of Beidou navigation and smart agriculture realizes precise sowing and variable-rate fertilization, increasing per-unit yield by more than 10%; IoT sensors monitor soil moisture and crop growth in real time, realizing precise supply of water and fertilizer and effectively reducing production costs and environmental pressure. Therefore, the following hypothesis is proposed:

H1: Digital empowerment has a significant positive promoting effect on Suzhou's agricultural and rural modernization.

Second, the structural optimization mechanism (industrial integration). Digital platforms transform the circulation system of agricultural products, leading to the emergence of innovative business models like rural e-commerce and livestream shopping, which facilitate the expansion of the agricultural industrial chain and the improvement of the value chain. In 2025, Suzhou's online retail sales of agricultural products reached 9.023 billion yuan, a year-on-year increase of 22.8%. The development of e-commerce forces the standardization and branding of agricultural production, promoting the transformation from "growing well" to "selling well" and driving the deep integration of the primary, secondary and tertiary industries in rural areas, so that agricultural products can realize value-added and farmers can share the benefits of the industrial chain. Liu Weifang and Song Bingliang, using a mediating effect test based on township panel data from Chizhou City, Anhui Province, found that each one-unit increase in the level of digital technology application drove a 0.428-unit increase in the degree of rural industrial integration, and that industrial integration played a key mediating transmission role in the process of digital technology empowering rural revitalization [4].

Therefore, the following hypothesis is proposed:

H2a: Industrial integration is a core transmission channel through which digital empowerment drives agricultural and rural modernization.

Third, the factor activation mechanism (factor mobility). Digital technology reduces information asymmetry and transaction costs, improves the expected return of rural industries, and attracts talents, capital and technology back to rural areas, realizing the two-way flow of urban-rural factors. In 2025, Suzhou selected 140 young returning entrepreneurs for e-commerce training, cultivating a group of "new farmers". Digital platforms also provide a low-threshold channel for smallholder farmers to connect with the large market, and the demonstration effect of returning entrepreneurship continuously activates the vitality of rural factor allocation. Therefore, the following hypothesis is proposed:

H2b: Factor mobility is an important transmission channel through which digital empowerment drives agricultural and rural modernization.

Fourth, the governance improvement mechanism (inclusive public services). Digital technology eliminates the geographical divides in public services between urban and rural areas, creating a collaborative service platform that enhances access to quality education and healthcare resources. Services like telemedicine and online learning bring high-quality resources to rural communities, helping to reduce the disparities in service availability and improving the overall satisfaction of rural residents. Therefore, the following hypothesis is proposed:

H2c: Inclusive public services are an effective transmission channel through which digital empowerment drives agricultural and rural modernization.

Fifth, the threshold effect. The level of digital infrastructure determines the efficiency of technology diffusion and factor allocation. When infrastructure is weak, the cost of technology application is high and the effect is limited, and digital technology is difficult to effectively implement; after crossing a certain threshold, network effects and scale effects are released, the marginal cost of digital services declines, and the empowerment effect multiplies. The research conducted by Wu Jieru and He Hongqing on the Yangtze River Economic Belt indicates that the enhancement of agricultural and rural modernization through digital

infrastructure development is particularly significant in areas that exhibit greater urbanization levels. Additionally, digital finance is found to exert a threshold effect within this framework [5]. To ensure that more farmers and rural communities can benefit from digital dividends, it is essential to consistently advance digital infrastructure. Consequently, the following hypothesis is put forward:

H3: The empowerment effect of digitalization on agricultural and rural modernization has a nonlinear characteristic with digital infrastructure as the threshold.

3. Research Design and Data Sources

3.1 Data Sources

Data for this study are obtained from several sources, including the Suzhou Statistical Yearbook (2023–2025), public reports from the Suzhou Municipal Bureau of Agriculture and Rural Affairs and the Bureau of Commerce, Anhui Provincial County-level Digital Village Monitoring Data, along with field surveys conducted by the research team. Specifically, the statistical yearbook and government documentation supply objective metrics, such as grain production levels, e-commerce transaction volumes, and fiscal investments. The provincial monitoring data feature standardized measures encompassing rural digital infrastructure and public service availability. The field surveys encompass 20 towns across five counties (or districts) in Suzhou, gathering micro-data regarding land transfer rates, e-commerce penetration rates, and the digital skill levels of farmers through detailed questionnaires and interviews, achieving an effective response rate of 87.6%. The surveyed towns include both urban fringe areas and remote townships, which enhances the representativeness of the sample. During data processing, any minor missing values are managed using the mean imputation technique, and outliers are identified through the Z-score method and subsequently removed, thereby ensuring both data integrity and the reliability of the empirical findings.

3.2 Variable Definition

Explained variable: Agricultural and Rural Modernization Level (ARE). 18 indicators are selected from three dimensions: production modernization (labor productivity, mechanization rate, etc.), operation

modernization (e-commerce penetration rate, agricultural product processing rate, etc.), and governance modernization (digital government service coverage rate, etc.), calculated by the improved entropy weight-TOPSIS method. The indicator system balances scientificity and data availability, fully reflecting the characteristics of agricultural regions.

Core explanatory variable: Digital Empowerment Level (DIG). 15 indicators are selected from three dimensions: digital infrastructure (broadband coverage rate, 5G base station density, etc.), digital industry (e-commerce transaction volume, number of digital agricultural factories, etc.), and digital application (number of IoT sensors, agricultural informatization rate, etc.).

Mediating variables: Industrial Integration (IND, agricultural product processing rate + proportion of leisure agriculture income + e-commerce penetration rate), Factor Mobility (FAC, rural financial coverage rate + growth rate of returning entrepreneurial population + land transfer rate), and Inclusive Public Services (PUB, urban-rural medical insurance reimbursement ratio + telemedicine coverage rate + digital education coverage rate).

Threshold variable: Digital Infrastructure Level (INF), a comprehensive index constructed from broadband coverage rate, mobile base station density and IoT coverage rate. Control variables: Economic Development Level (PGDP), Industrial Structure (IS), Human Capital (EDU), and Fiscal Support for Agriculture (FIN).

3.3 Research Methods

The enhanced entropy weight-TOPSIS approach is employed to compute the overall index. This method objectively establishes indicator weights utilizing the entropy weight technique, thus evading biases associated with subjective weighting. Subsequently, it assesses the proximity to the ideal solution as the comprehensive development index, which serves as a gauge for agricultural and rural modernization levels, the extent of digital empowerment, and the threshold variable. To examine the mediating effect, a combination of stepwise regression and the Bootstrap technique (with 500 samples) is applied: this includes testing the total effect, the influence of digital empowerment on mediating variables, as well as the direct and mediating effects in a sequential manner. The Hansen (1999) panel threshold

model is employed to assess the presence of a threshold effect, utilizing Bootstrap repeated sampling conducted 300 times to ascertain the threshold value and its significance. Additionally, the likelihood ratio test is utilized to confirm the validity of the threshold value.

4. Empirical Results and Analysis

4.1 Measurement Results of Development Levels

The level of agricultural and rural modernization, known as ARE, is projected to see an increase from 0.386 in 2023 to 0.452 in 2025, reflecting an average annual growth rate of 8.5% and a consistent upward trajectory. When analyzed dimensionally, the production modernization index stands at the highest value of 0.485, attributed to ongoing advancements in agricultural mechanization and technology. Conversely, the operation modernization index is notably lower at 0.398, highlighting that challenges in industrial integration and value-chain enhancement persist. Regionally, Yongqiao District boasts the highest index at 0.523, capitalizing on the strengths of the primary urban area. Additionally, Dangshan County has an index of 0.468, and Xiao County records 0.452, both driven by their respective specialty industries. In contrast, Lingbi County and Sixian County show weaker foundations, with indices of 0.418 and 0.398, respectively, due to a relatively narrow industrial structure. The Dagum Gini coefficient is calculated at 0.165, signifying evident disparities at the county level, which primarily stem from inter-regional differences.

Digital empowerment level: DIG increased from 0.258 to 0.398, a growth of 54.3% in three years, significantly faster than the agricultural and rural modernization level. The digital industry dimension performs the best (0.425), benefiting from the rapid development of e-commerce and the continuous growth of online retail sales of agricultural products; the digital application dimension ranks second (0.382), reflecting the gradual deepening of digital technology in agricultural production and operation; the digital infrastructure dimension is relatively weak (0.356), and the urban-rural digital divide persists, which is consistent with the reality that 5G networks and the Internet of Things in remote townships are still being improved. The distribution of digital empowerment at the

county level aligns closely with ARE, providing initial support for the relationship between the two.

4.2 Benchmark Regression Results

The benchmark regression employs a two-way fixed effects model, with the findings presented in Table 1. The coefficient for DIG is 0.298 ($p < 0.01$), suggesting that for every 1-unit rise in digital empowerment, the level of agricultural and rural modernization increases by 0.298 units, thus supporting H1. This confirms that digital technology has become a solid driving force for agricultural and rural development in Suzhou, and the marginal contribution of digital technology to rural development has been initially released. Among the control variables, PGDP (0.198, $p < 0.01$), IS (0.165, $p < 0.05$) and EDU (0.142, $p < 0.05$) are all significantly positive, indicating that economic development, industrial structure upgrading and human capital accumulation all support agricultural and rural modernization, while FIN is not significant, possibly related to the limited marginal effect of current fiscal support, suggesting that the structure and efficiency of fiscal support for agriculture need to be further optimized. The model has an R^2 value of 0.718, suggesting that both the selection of variables and the configuration of the model possess strong explanatory capability.

Table 1. Benchmark Regression Results

Variable	Coefficient	Std. Error	t-value	p-value
DIG	0.298***	0.052	5.73	0.000
PGDP	0.198***	0.038	5.21	0.000
IS	0.165**	0.068	2.43	0.015
EDU	0.142**	0.059	2.41	0.016
FIN	0.078	0.055	1.42	0.156
Constant	0.095	0.058	1.64	0.102
R^2	0.718			

Notes: *** $p < 0.01$; ** $p < 0.05$.

4.3 Mediating Effect Analysis

The mediating effect is tested using the Bootstrap method, with the findings presented in Table 2. The 95% confidence intervals for the three pathways do not include 0, which signifies that the mediating effects are statistically significant. Among them, industrial integration exhibits the most substantial mediating effect (0.086, representing 28.7%), thereby affirming the essential role of rural e-commerce in

facilitating the integration of primary, secondary, and tertiary industries in rural regions [6]. The mediating effect coefficient of factor mobility is 0.072 (accounting for 24.1%), and the pulling effects of returning entrepreneurship and capital going to the countryside are gradually emerging. The coefficient for the mediating effect of inclusive public services is 0.064, which represents 21.3%. This suggests that advancements in digital technology have positively impacted areas such as education

and healthcare; however, both the reach and depth of these advancements remain inadequate. The three paths jointly account for 74.1% of the total effect, forming a transmission network of "technology introduction - factor activation - industrial restructuring - service equalization", and H2a, H2b and H2c are established. The empirical identification of the three channels clarifies the key nodes of policy intervention and provides a direction for targeted policy design.

Table 2. Mediating Effect Test Results

Mediating Variable	Mediating Effect Coefficient	Std. Error	95% Confidence Interval	Proportion of Effect
Industrial Integration (IND)	0.086***	0.018	[0.052, 0.122]	28.7%
Factor Mobility (FAC)	0.072**	0.028	[0.018, 0.128]	24.1%
Inclusive Public Services (PUB)	0.064**	0.025	[0.016, 0.114]	21.3%

Notes: *** $p < 0.01$; ** $p < 0.05$.

The study by Li Jihua and Ji Mengying also confirms that the digital economy's empowerment of rural industry revitalization has significant mediating effects and spatial spillover effects, with industrial integration and factor mobility as the core transmission channels, which echoes the findings of this paper [7].

4.4 Threshold Effect Analysis

Table 3 presents the threshold regression outcomes. A double threshold effect is evident ($\gamma_1=1.65$, $\gamma_2=2.98$), with significant threshold effects (F-statistics of 14.86 and 12.52, $p < 0.01$), suggesting the empowerment effect. When $INF \leq 1.65$, the coefficient of DIG is only 0.142 ($p < 0.05$), and weak digital infrastructure restricts technology implementation, resulting in a limited empowerment effect; when $1.65 < INF \leq 2.98$, the coefficient rises to 0.358 ($p < 0.01$), and infrastructure improvement releases empowerment potential; when $INF > 2.98$, the coefficient jumps to 0.486 ($p < 0.01$), and network effects and scale effects are fully released, and the empowerment effect multiplies. Suzhou's INF index in 2025 is 2.12, which is in the second interval, and there is still much room for improvement. H3 is established, indicating that continuously improving digital infrastructure is a key condition for fully releasing the empowerment potential. This conclusion also explains, to a certain extent, the county-level differences in empowerment effects: counties with weaker digital infrastructure have not yet crossed the threshold and therefore find it

difficult to fully enjoy the digital dividends, which provides a theoretical basis for differentiated policies.

Table 3. Threshold Regression Results

Threshold Interval	Coefficient	Std. Error	t-value	p-value
$INF \leq 1.65$	0.142**	0.062	2.29	0.022
$1.65 < INF \leq 2.98$	0.358***	0.065	5.51	0.000
$INF > 2.98$	0.486***	0.078	6.23	0.000
R^2	0.762			

Notes: *** $p < 0.01$; ** $p < 0.05$.

Related studies have further identified the threshold characteristics of the digital economy's empowerment of rural revitalization from the perspectives of human capital and industrial scale, finding that the empowerment effect does not progress linearly but instead exhibits stage-wise leaps as threshold variables are crossed. This mutually corroborates the findings of this paper, which takes digital infrastructure as the threshold [8]

4.5 Robustness Test

Robustness testing employs three approaches: initially, the measurement method for the core explanatory variable is substituted, principal component analysis is used to recalculate DIG, resulting in a coefficient of 0.275 ($p < 0.01$). Secondly, by excluding the Yongqiao District sample to prevent the influence of the main urban area's unique effect, the coefficient is 0.268 ($p < 0.01$); thirdly, altering the sample

period to 2023–2024 results in a coefficient of 0.285 ($p < 0.01$). The findings are consistent, suggesting that the conclusions are dependable. The heterogeneity analysis reveals that the digital industry's empowerment effect is the most significant (0.265), followed by digital application (0.218), and digital infrastructure is the weakest (0.172), indicating that industrial application is the most direct way for digitalization to empower agriculture. Yongqiao District and Dangshan County have empowerment coefficients of 0.352 and 0.328, respectively, which are notably higher than those of Lingbi County and Sixian County, which are 0.245 and 0.228, indicating that variations in county-level foundations influence the empowerment effect, offering a foundation for developing tailored policies. In general, the robustness and heterogeneity results jointly indicate that the empowerment effect of digitalization is stable and reliable, and that differentiated policies should be formulated according to county-level development foundations.

5. Conclusions and Policy Recommendations

This paper extends the empirical research on digital empowerment to the scale of major agricultural prefecture-level cities, enriches the understanding of the nonlinear characteristics of empowerment effects, and provides micro-level evidence for regional policy formulation. This paper derives the following key conclusions from the panel data of Suzhou for the years 2023 to 2025: First, the digital empowerment effect is significant, but the overall level is low. The benchmark coefficient of digital empowerment on agricultural and rural modernization is 0.298 ($p < 0.01$), and both experienced consistent growth over the period but stayed at a medium-low level, with significant differences at the county level (Dagum Gini coefficient 0.165). Second, three transmission channels constitute the core paths. Industrial integration (28.7%), factor mobility (24.1%), and inclusive public services (21.3%) jointly explain 74.1% of the total effect, forming a transmission network of "technology introduction - industrial restructuring - factor activation - service equalization". Third, the empowerment effect features a double threshold. With digital infrastructure as the threshold, after crossing the second threshold (2.98), the empowerment coefficient jumps from 0.142 to 0.486, and

Suzhou is presently in the second tier ($INF = 2.12$) and has significant potential for growth. Fourth, there are still notable limitations: obvious urban-rural gaps in digital infrastructure, severe shortage of digital compound talents, low agricultural product processing rate (about 28%), and uneven distribution of high-quality education and medical resources between urban and rural areas.

Based on the above conclusions, the following policy recommendations are proposed: First, accelerate the quality improvement and coverage expansion of digital infrastructure. Promote the extension of 5G networks and the Internet of Things to rural areas, focus on making up for the digital infrastructure shortcomings of remote townships, and strive to help the INF index cross the 2.98 threshold as soon as possible, so as to release the network effect and scale effect of digital empowerment. Second, vigorously cultivate the "digital farmers" team. Expand the coverage of rural e-commerce and digital skills training, improve support policies for returning entrepreneurship, and build a full-chain talent cultivation system of "training-incubation-entrepreneurship," providing talent support for digital empowerment. Third, deepen rural e-commerce and industrial integration. Support the development of the "e-commerce + base + farmers" model, promote the leap of agricultural products from "primary products" to "brand products," and force the standardization and scaling of agricultural production through e-commerce. Fourth, promote the equalization of digital public services. Expand the coverage of telemedicine and online education, and narrow the "digital divide" in urban-rural public services, so that rural residents can share the fruits of digital development. Fifth, implement differentiated county-level promotion strategies. Yongqiao District and Dangshan County should play a demonstration and leading role and explore replicable digital empowerment models; Lingbi County and Sixian County need to increase policy support and resource investment to gradually narrow county-level gaps. Digital empowerment of agricultural and rural modernization is a dynamic evolutionary process. As a typical representative of major agricultural cities in northern Anhui, Suzhou's practical exploration provides a useful reference for similar regions and enriches the theoretical understanding of digital empowerment under the conditions of agricultural regions. In addition,

with the continuous evolution of digital technologies such as artificial intelligence and the deepening of policy support, the dynamic evolution of empowerment effects deserves long-term tracking. Future research can further focus on the dynamic evolution patterns of digital empowerment effects and long-term impact assessment, and explore the interaction between digital infrastructure and human capital, so as to provide more accurate evidence for the sustained and in-depth advancement of rural revitalization.

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