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Unlocking the Integration Mechanism: How Digital Village Construction Promotes Agro-Cultural-Tourism Development through Rural E-Commerce

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Globally, rural revitalization requires new drivers. China’s Digital Village Construction (DVC) offers a strategic context to examine how digitalization fosters rural industrial integration, specifically in agriculture, culture, and tourism (ACT).Utilizing cross-sectional data from 225 counties in China’s Yangtze River Delta, we construct a comprehensive ACT integration evaluation index. Instrumental variable and mediation effect models empirically analyze DVC’s impact mechanism, focusing on rural e-commerce’s mediating role.The findings indicate that:(1) ACT integration shows significant regional disparity, with higher levels in Zhejiang Province compared to Jiangsu and Anhui. (2) DVC significantly promotes ACT integration both directly and indirectly through rural e-commerce. Digital finance, cultural tourism, and marketing empower e-commerce with capital, talent/technology, and market access, respectively, driving integration. (3) The promoting effects of DVC dimensions rank (descending): infrastructure, life, economic, and governance digitization.The study elucidates a clear sequential pathway in which the construction of digital infrastructure facilitates the activation of rural e-commerce platforms, which in turn drives deeper integration among agriculture, culture, and tourism industries. These findings provide critical empirical evidence for optimizing digital village policies to foster synergistic rural industrial development and revitalization.

Keywords: digital village construction；agro-cultural-tourism integration； rural e-commerce； mediating effect； rural revitalization； China

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1 Introduction

Rural areas worldwide stand at a critical juncture, confronting multifaceted challenges including population outflow, economic marginalization, and pressing imperatives for sustainable development. In this context, digital transformation has emerged as a transformative force with the potential to fundamentally reshape rural futures (Majchrzak et al., 2016). This transformation transcends mere technological adoption, representing a profound restructuring of economic structures, social networks, and livelihood opportunities. In China, this dynamic is particularly salient. The national Rural Revitalization Strategy explicitly positions digitalization as a core lever for bridging the urban rural development gap and fostering comprehensive rural advancement (Liu & Liu, 2024; Zhao et al., 2022). Within this strategic framework, the integrated development of agriculture, culture, and tourism (commonly termed ACT integration) has gained considerable traction as a synergistic model. It promises to enhance local resource value, diversify rural economies, and improve community well-being, thereby directly contributing to the goals of sustainable rural revitalization (Qin et al., 2025; Shi & Liao, 2025).

Existing scholarship has actively examined various facets of this transformational process. A significant stream of literature investigates the drivers and impacts of rural e-commerce, demonstrating its capacity to reconfigure rural economies by forging new market linkages, fostering entrepreneurship, and altering spatial development patterns (Liu & Zhou, 2023; Wang et al., 2021; Zang et al., 2025). Concurrently, another vital line of inquiry focuses on the role of digital infrastructure and financial instruments. Research confirms that digital village construction and digital inclusive finance can empower rural actors, optimize resource allocation, and stimulate industrial upgrading, thereby accelerating high-quality economic development and narrowing income disparities (Mei et al., 2022; Xu et al., 2024; Zeng & Zhou, 2025). Furthermore, a growing body of work analyzes the ACT integration model itself, scrutinizing its economic performance, spatial dynamics, and prerequisites for success (Fang et al., 2023; Ma et al., 2024; Zhong et al., 2022).

Despite these valuable contributions, a critical research gap persists. Prior studies have predominantly examined digital village construction, rural e-commerce, and ACT integration in relative isolation or through pairwise relationships (e.g., exploring digital finance and industry integration [Huang et al., 2023], or e-commerce and rural transformation [Wang et al., 2021]). This fragmented approach has overlooked the exploration of a coherent, sequential, and multiplier-integrated mechanism that connects these three powerful elements. Specifically, we lack a systematic understanding of how the foundational digital ecosystem, built through digital village initiatives, activates and channels the dynamism of rural e-commerce to specifically catalyze and sustain the complex process of ACT integration. Although digitalization is widely acknowledged as an enabling force, the concrete operational pathways remain insufficiently explored and theoretically underdeveloped. This is particularly true for understanding how e-commerce platforms transform local agricultural products into cultural commodities, facilitate demand-driven tourism experiences, or enable novel consumer-producer interactions that fuse these sectors (Kusumastuti et al., 2024; Yang & Ning, 2025). This constitutes a significant theoretical and empirical lacuna. Without unveiling this integrative mechanism, policymakers and practitioners lack a nuanced blueprint for strategically sequencing investments and interventions to maximize synergistic outcomes. Consequently, a pivotal question remains unanswered: **Through what specific pathways and processes does digital village construction, mediated by rural e-commerce, drive the effective and sustainable integration of agriculture, culture, and tourism?**

This study aims to address this critical gap by proposing and investigating a holistic integration mechanism. We posit that rural e-commerce is not merely a downstream outcome of digital villages nor a parallel development track to ACT integration. Instead, it functions as an essential transmission belt and effect amplifier, connecting foundational digital infrastructure to multidimensional industry fusion. The core objective of this research is to empirically uncover and theoretically explicate the mechanism through which digital village construction promotes ACT integration via the mediating role of rural e-commerce. To this end, we investigate the following specific research questions: (1) What is the direct impact of digital village construction on the level of ACT integration? (2) Does the development of rural e-commerce serve as a significant mediating channel in this relationship? (3) Within this mediating role, through which specific pathways (e.g., market expansion, brand building, data feedback, entrepreneurial incubation) does e-commerce translate digital capabilities into

integrated ACT outcomes?

The contributions of this study are threefold. First, it moves beyond isolated or pairwise analyzes to construct and test an integrated theoretical framework that explicitly links rural digital foundations, the platform economy, and industry integration, thereby offering a more granular and holistic understanding of the digital rural transformation process. Second, by identifying and validating rural e-commerce as a key mediator, the study provides actionable insights for policymakers, suggesting that strategically nurturing a vibrant e-commerce ecosystem is a critical fulcrum for achieving rural integration and revitalization objectives. Third, the investigation into specific mediation pathways enriches the literature on the digital economy and rural revitalization by elucidating the micro-mechanisms that underpin macro-development outcomes, such as how online visibility enhances cultural-tourism attractiveness or how supply chain digitalization creates value for agri-tourism products. Ultimately, this study provides a coherent explanatory model to unlock the synergistic potential of digitalization in cultivating sustainable and prosperous rural futures.

2 Theoretical Analysis and Hypothesis Development

2.1 Direct Impact Mechanism of Digital Village Construction

The framework of DVC encompasses four interrelated yet distinct dimensions: the digitization of rural infrastructure, the rural economy, rural life, and rural governance. Systematically examining DVC's potential influence on industry integration across these dimensions facilitates the formulation of targeted strategies and enhances the breadth and depth of its developmental impact.

2.1.1 Impact of Rural Economic Digitization.

The core of DVC focuses on rural economic digitization, which profoundly shapes and propels the comprehensive development of rural industries through multiple avenues, including digital production, digital supply chains, and digital finance. Digital production leverages technologies such as the Internet of Things (IoT) and big data analytics to enable precise and efficient transformation across the entire agricultural industrial chain(Jia & Zhu, 2025; Lu et al., 2025) . This improves the agricultural input-output ratio and can generate a multiplier effect on the rural economy(Zhang & Diao, 2020). Digital supply chains optimize smart logistics services, a critical nexus

connecting production, processing, and sales. The digital transformation of logistics is vital for streamlining end-to-end operations, reducing costs, and improving efficiency. Concurrently, the emergence of digital supply chain finance, through the deep integration of operational data and financial services, not only smoothens agricultural product circulation but also helps mitigate capital chain disruptions, providing more robust and accessible financial support for rural industries. In the context of financing for integrated development, digital finance can lower credit thresholds and promote both industrial convergence and financial service diversification. Traditional financial institutions often impose stringent lending criteria due to difficulties in assessing rural creditworthiness. Digital finance circumvents these barriers through advanced technologies like big data and cloud computing, which enable more accurate risk profiling. This facilitates the fusion of agriculture with other rural industries and offers rural residents and businesses a more diverse array of financial products and services.

2.1.2 Impact of Infrastructure Digitization.

In the process of building digital villages, information infrastructure and financial infrastructure are closely intertwined and mutually reinforcing, collectively providing a strong foundation for the comprehensive development and upgrading of rural industries(W. Chen & Song, 2025; Lai et al., 2024). On the one hand, enhancing information infrastructure(e.g., broadband networks, 5G coverage, and data centers) is a cornerstone of DVC. It not only boosts information transmission efficiency in rural areas but also fosters a technological innovation effect by providing the necessary backbone for new applications and services. The foundational data resource systems enabled by this infrastructure can integrate ACT resources, activate ACT elements, and thereby drive innovation in agricultural marketing models, aid in brand and cultural development, and expand tourism reach(Gans Combe & Camaréna, 2025; Gebresenbet et al., 2023). On the other hand, upgrading financial infrastructure is also dependent on robust information infrastructure. Initiatives like the "credit express" model, which streamlines loan applications for farmers, are made feasible by improved information systems that allow for data sharing and remote processing. As the utilization and sophistication of county-level digital financial infrastructure deepens, the inclusiveness of digital finance is further amplified, directly addressing historical gaps and deficiencies in rural financial service provision. Consequently, financial institutions can better serve the rural economy and meet the diverse and often specific financing needs of emerging ACT industries.

2.1.3 Impact of Rural Governance Digitization.

Compared to urban areas, China's rural economic development has historically lagged, with slower progress in transportation, network infrastructure, and overall informatization levels. This has resulted in underdeveloped digital financial infrastructure and credit systems. A key consequence is acute information asymmetry between financial institutions and farmers, making accurate credit assessment challenging under traditional frameworks and potentially excluding rural households from the benefits of inclusive finance(Khan et al., 2024). The advancement of DVC propels rural governance toward greater systematization, intelligence, and efficiency, which in turn facilitates the establishment of rural big data credit systems(Xu et al., 2026; X. Yang et al., 2025). The new rural credit system is essentially a big data-driven credit framework built on digital platforms. Characterized by diversified, multi-dimensional information integration encompassing comprehensive financial and non-financial data (e.g., utility payments, social insurance records), its value extends far beyond traditional inclusive finance. It should function as a public good, providing solid data support and a decision-making basis for various endeavors, including rural industrial development, employment promotion, and entrepreneurship support. Furthermore, as digital governance tools gain wider coverage, local governments and stakeholders can utilize them to construct systematic ACT industry integration index systems. Such systems can precisely identify bottlenecks within the integration process, objectively evaluate progress and developmental stages, and comprehensively analyze the effectiveness of policy implementation. They also offer valuable decision support to financial institutions, enabling them to swiftly grasp the status and trends of rural ACT industries for more precise and timely capital allocation.This synergy between data-driven governance and finance fosters innovation, allowing institutions to develop tailored financial products and service models that effectively support ACT integration, exemplified by supply chain finance and green finance.

2.1.4 Impact of Rural Life Digitization.

A central tenet of DVC is to promote the digitization of rural life, enhancing the quality and convenience of daily living. Life digitization permeates various domains, including consumption, healthcare, tourism, and entertainment(B. Chen & Xiao, 2025). Digital consumption dissolves the traditional spatiotemporal constraints associated with simultaneously accessing agricultural, cultural, and touristic products and experiences.

It blurs industrial boundaries and fosters the emergence of cross-sectoral consumption patterns. For instance, a consumer might purchase local specialty food online (agriculture), watch a video about its cultural heritage (culture), and then book a farmstay experience (tourism) through the same digital platform. In this process, digital technology not only reshapes the development and marketing of cultural-creative products and tourism services but also significantly stimulates latent demand through innovative applications and immersive content. Moreover, facilitated by wider access to digital tools and the internet, rural residents can obtain quality educational resources at lower cost. This substantially improves their digital literacy and technical skills while increasing their participation in and understanding of digital financial markets. This upskilling meets diverse spiritual and cultural needs and, crucially, creates a more favorable human capital environment for ACT integration. Research suggests that online social interactions can be more effective than traditional offline ones in promoting rural residents' engagement with digital finance, enhancing their financial literacy. Simultaneously, supported by digital inclusive finance which broadens financing channels and reduces financial exclusion, entrepreneurial activities among rural residents are effectively encouraged. This contributes to income growth and helps narrow the urban rural income gap, creating a more vibrant local economy that can support integrated tourism and cultural ventures.

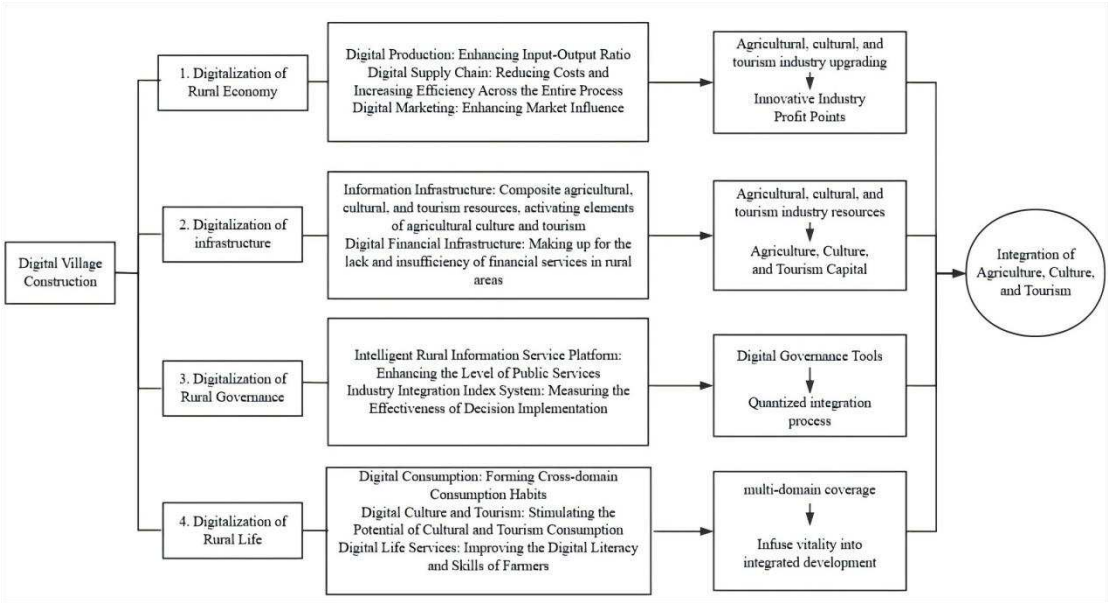

Fig.1 : Analysis of the direct mechanism of digital village construction affecting the integration of agriculture, culture and tourism

Based on the preceding analysis, we propose the following hypotheses concerning direct effects:

H1: Digital village construction has a significant positive effect on the development level of agro-cultural-tourism integration.

H2: The positive influence of digital village construction on agro-cultural-tourism industry integration operates through four distinct dimensions: rural economic digitization, infrastructure digitization, rural governance digitization, and rural life digitization.

2.2 The Mediating Role of Rural E-commerce

As a significant and dynamic component of DVC, rural e-commerce provides essential capital, talent, technology, and market access support for ACT industries, holding profound implications for achieving integrated development. By utilizing internet platforms to connect diverse rural specialty resources with broader markets, rural e-commerce expands economic opportunities while its physical logistics and service terminals become rooted in grassroots communities. These terminals often evolve into multifunctional service stations, providing not just e-commerce facilitation but also information and services related to agriculture, rural affairs, and farmer welfare. With the deepening implementation of the digital village strategy, the scale and sophistication of rural e-commerce continue to grow. It plays an active role in infusing cultural narratives and tourism elements into the production, branding, and marketing of traditional agricultural products. This activity drives coordinated flows of logistics, technology, talent, and capital. Furthermore, it fosters the development of virtual industrial clusters that enhance resource integration and specialization within industry chains. This ecosystem enables mutually beneficial collaboration among ACT producers, e-commerce platforms, and logistics firms through mechanisms like data sharing and cooperative business models.

2.2.1 Financing Empowerment: Alleviating Capital Constraints.

The development of a robust rural e-commerce sector can elevate the level of digital finance adoption and improve the overall financing environment in rural areas(B. Chen & Xiao, 2025). As a core strategy for accelerating rural modernization, the burgeoning e-commerce sector creates precise and efficient application scenarios for innovative internet finance solutions and establishes key transactional and data infrastructure for rural digital inclusive finance. As an integral part of the e-commerce

ecosystem, digital inclusive finance significantly expands the effective reach of financial services, profoundly impacting rural industrial development through reliable payment and settlement services, enhanced credit support based on transactional data, and improved financing conditions(Abbas et al., 2024). Digital finance offers superior precision and efficiency in service delivery. Externally, major financial institutions are increasingly deploying agricultural e-commerce systems, leveraging big data models derived from platform transaction histories, customer reviews, and logistics performance to assess the creditworthiness of smallholder farmers and rural businesses. This allows for expedited online loan processing, better risk management, and the deep embedding of financial services into industry chains by seamlessly meeting diverse payment needs. Local banks and credit unions are exploring partnerships with leading e-commerce platforms for co-development. Internally, large e-commerce platforms can offer their own financing models, such as bank linkage programs or platform-based microloans (often via licensed microfinance companies), using sellers' order histories and future sales projections as collateral for working capital financing. The expansion and diversification of these financing channels incentivize more entrepreneurs, small enterprises, and cooperatives to engage in the ACT sector. Leveraging e-commerce's inherent supply chain financing advantages can significantly improve the financing efficiency for ACT industries, injecting vital liquidity and encouraging investment in quality upgrades and integration initiatives.

2.2.2 Talent Agglomeration: Fostering Technological and Business Model Innovation.

Rural e-commerce acts as a powerful magnet and incubator for talent, supplying the human capital and technical support necessary for ACT industries to innovate and upgrade(Cui et al., 2024). Policy directives, such as those emphasized in the 2024 Central Document No. 1, call for the in-depth implementation of initiatives like "Digital Commerce Revitalizes Agriculture" and the "Internet Plus" program for agricultural products, which aim to better connect rural production with urban markets(Peng et al., 2025). The parallel rise of digital cultural tourism has generated numerous new professions and positions in rural areas, ranging from content creators and social media managers to experience designers and data analysts, thereby attracting and retaining a cohort of digitally savvy “new farmers.” Drawn by the opportunities of the digital economy and the relatively low barriers to entry, innovative approaches, and high

potential returns of e-commerce, many young people and urban professionals are returning to their hometowns to start businesses, with a significant focus on e-commerce ventures(Yin et al., 2026). These returnees often possess either direct e-commerce expertise or valuable urban social networks and consumer insights. They accelerate the reciprocal flow of urban and rural resources, ideas, and capital. As these entrepreneurial youth frequently lead the management, curation, and marketing of rural e-commerce stores (especially for higher-value-added cultural-tourism products), they facilitate the infusion of modern marketing concepts, design thinking, and customer service standards into rural business practices. They also help interpret and respond to diverse urban consumer demands, thereby promoting the backward integration of primary agriculture into processing, packaging, branding, and services, which is essential for catalyzing deeper rural industrial fusion. By building on local agricultural, cultural, and tourism resources, these entrepreneurs use e-commerce platforms and digital skills to deeply integrate and creatively present characteristic rural industries. This transforms local economic production from singular, commodity-focused agriculture toward integrated ACT development that sells stories, experiences, and identities alongside products. This strengthens inter-industry synergy, helps communities overcome perceived resource constraints, accelerates the adoption of relevant technologies, mitigates talent drain, and ultimately empowers a more resilient and innovative form of rural industrial integration.

2.2.3 Information Symmetry: Enhancing Market Efficiency and Reach.

As a fusion of information technology and the rural economy, the development of rural e-commerce, supercharged by digital marketing tools, effectively breaks down historical information silos between rural producers and urban or global consumers. It provides significant market traffic, brand visibility, and direct access support that is crucial for ACT integration. Live-streaming commerce, a dominant new e-commerce model aligned with the visual and interactive consumption preferences of younger generations, injects new vitality and immediacy into rural product markets(Cheng et al., 2025). Compared to traditional advertising or social media promotion, e-commerce platforms and live-stream hosts can analyze audience preferences in real-time and craft narratives that highlight product quality, cultural heritage, and artisanal processes(G. Yang et al., 2024). This allows them to directly connect rural specialty products with

engaged consumers, influencing purchase decisions and trends while effectively transcending geographical limits. By utilizing platform data analytics and text sentiment analysis, combined with insights into consumer psychological tendencies and cultural affinities, sellers can achieve more objective user segmentation, personalized tagging, and targeted content delivery. This enables potential consumers to more easily discover, understand, and develop an affinity for rural ACT products and the places they come from. Furthermore, integrating the logistical robustness of traditional e-commerce with the engagement power of live-streaming enhances operational efficiency across the entire industrial chain, from attracting customer traffic to managing supply and fulfilling orders. The stringent product selection criteria and quality expectations of top live-streamers and reputable platforms compel upstream supply chain upgrades, standardization, and quality control. This market-driven pressure aids in building trustworthy, distinctive county and village-level brands that can command a premium. With its relatively low entry barriers, potentially global reach, and capacity for rapid innovation, rural e-commerce creates vast market prospects for ACT industries. Bolstered by targeted digital marketing and the network effects of popular platforms, it enhances the economic viability, competitiveness, and scale potential of industrial integration, promoting a more sustainable development model. By empowering specific pilot enterprises or cooperatives in a point-to-area demonstration effect, e-commerce enables real-time market feedback on supply and demand, facilitating efficient two-way matching, dramatically reducing information asymmetry, and continuously opening new sales channels, customer segments, and product or service domains for the evolving ACT sector.

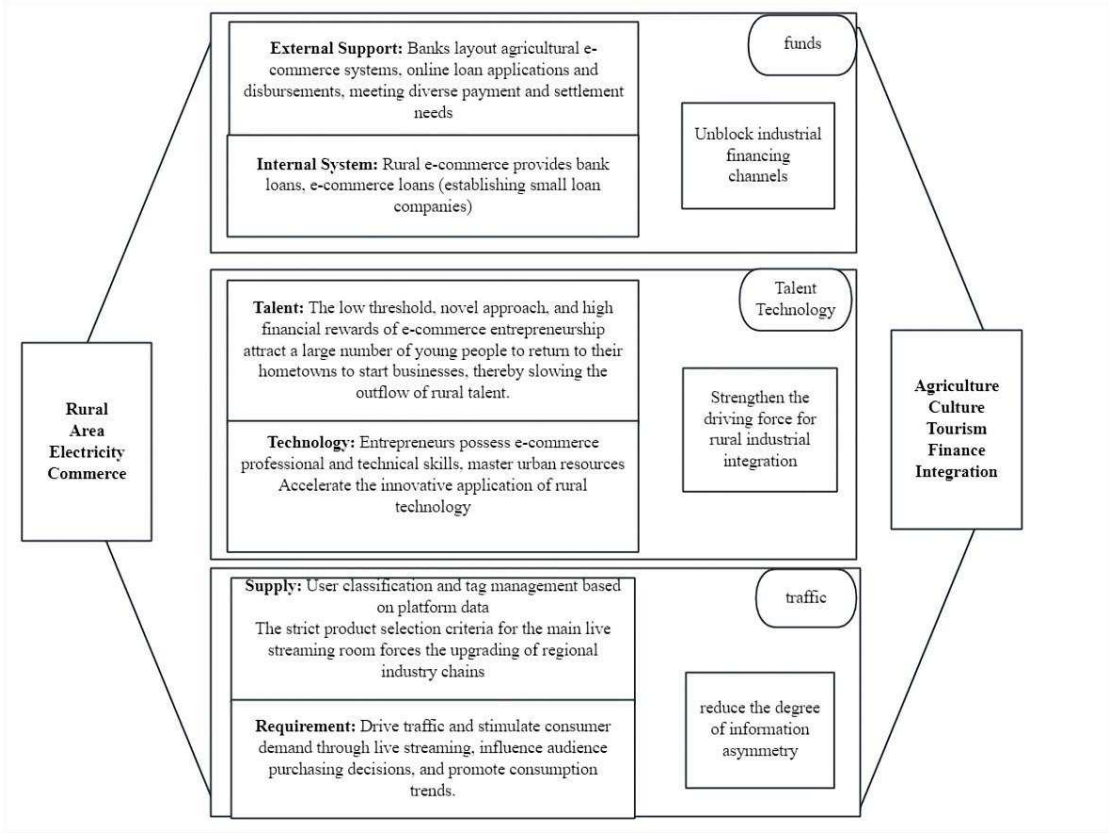

Fig.2 Analysis of the indirect mechanism of digital village construction affecting the integration of agriculture, culture and tourism

Accordingly, we propose the following hypothesis regarding the mediating mechanism:

H3: The positive influence of digital village construction on agro-cultural-tourism industry integration is significantly mediated by its positive impact on the development of rural e-commerce. Digital village construction empowers rural e-commerce, which in turn becomes a direct driver of ACT integration.

3 Data and Methodology

3.1 Data and Variables

This study utilizes cross-sectional data from 225 counties in China's Yangtze River Delta region (Zhejiang, Jiangsu, and Anhui provinces) for the reference year 2020. To ensure comparability in the core index measurement and focus on counties where rural revitalization through digital means is a primary policy concern, Shanghai and other highly urbanized district-level units within the region were excluded from the sample.

3.1.1 Dependent Variable:

ACT Integration Level (Integration). The dependent variable is a composite measure representing the comprehensive development level of ACT integration at the county level. Reflecting the multi-dimensional nature of integration and its potential within the DVC context, 14 specific indicators were selected across three foundational pillars: characteristic agriculture, rural tourism, and local culture (see Table 1 for the full list). To synthesize these indicators into a single score and mitigate multicollinearity, factor analysis was conducted using SPSS software. The analysis extracted three principal factors with eigenvalues greater than 1, which were interpreted and named as follows: the Cultural-Tourism Resources Factor (loading highly on indicators like A-level scenic spots, historic towns), the Industrial Support Factor (loading on indicators like "One Village, One Product" demonstration sites, e-commerce demonstration counties), and the Brand Effect Factor (loading on indicators like nationally recognized agricultural heritage and intangible cultural heritage). The factor scores for each county were calculated, and a final comprehensive integration score was derived as a weighted sum of these factor scores, with weights proportional to the variance explained by each factor.

Table 1 Indicators of the development level of agriculture, culture and tourism

Indicator category	The name of the metric	Data source
Specialty Agriculture	National Geographical Indications for Agricultural Products	Ministry of Agriculture and Rural Affairs
	One Village, One Product	Ministry of Agriculture and Rural Affairs
	Advantageous area of Chinese characteristic agricultural products	Ministry of Agriculture and Rural Affairs
	Leisure agriculture demonstration county	Ministry of Agriculture and Rural Affairs, Tourism Bureau
	E-commerce into rural demonstration counties	People's Republic of China the market system of the Ministry of Commerce
Vernacular culture	List of famous historical and cultural towns in China	Ministry of Housing and Urban-Rural Development
	Traditional Chinese villages	Ministry of Housing and Urban-Rural Development
	China's Important Agricultural Cultural Heritage	Ministry of Agriculture and Rural Affairs
	National intangible cultural heritage	Ministry of Culture and Tourism
Rural tourism	National Rural Governance Demonstration Township	Ministry of Agriculture and Rural Affairs
	A-level scenic spot	Ministry of Culture and Tourism
	National characteristic landscape tourist town	Ministry of Housing and Urban-Rural Development
	Forest village	National Forestry and Grassland Administration

To assess spatial variations in the integrated development of agriculture, culture, and tourism (ACT) across counties in the Yangtze River Delta, we constructed a comprehensive evaluation system using factor analysis. County-level composite scores were derived through weighted summation and mapped spatially with ArcGIS (Fig. 3). The results indicate pronounced regional disparities in ACT development. Counties in Zhejiang Province generally attained higher scores, predominantly falling within the intervals of (0.36, 0.76) and (0.76, 1.39). Several counties in Jiangsu, including Xinghua, Dongtai, and Liyang, also demonstrated relatively high scores, largely within the range of (0.36, 0.64). By contrast, Anhui Province displayed lower overall performance, with most counties scoring between (- 0.15, 0.18), and northern Anhui notably trailing southern Anhui. These outcomes imply that ACT integration is closely linked to regional resource advantages, economic conditions, and policy frameworks. Moving forward, it is essential to deepen the understanding of driving mechanisms and foster distinctive local brands to enhance coordinated regional development.

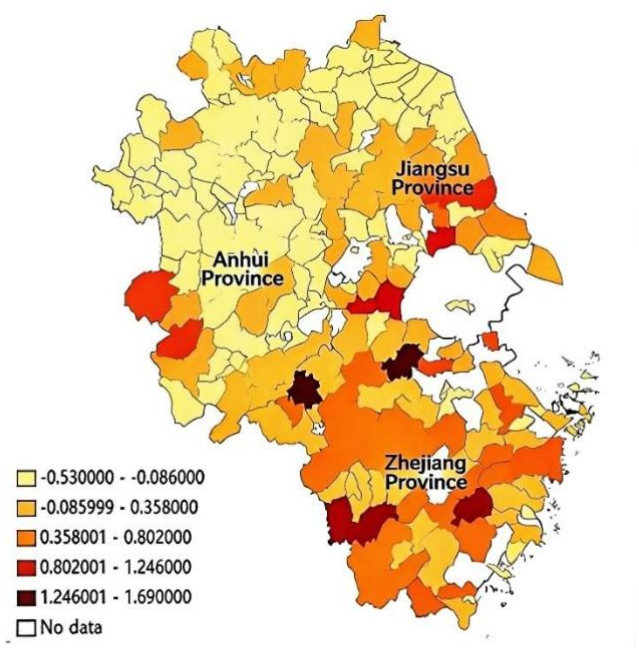

Figure 3: Spatial distribution of ACT integration scores in the Yangtze River Delta

3.1.2 Independent Variable: Digital Village Index (Dc).

The core independent variable is the county-level Digital Village Index for 2020, sourced from the authoritative County Digital Village Index (2020) research report. This comprehensive index, developed by a leading research consortium, systematically

assesses the breadth and depth of rural digitalization. It encompasses four primary dimensions: rural economic digitization (eco), rural digital infrastructure (infra), rural governance digitization (admin), and rural life digitization (life). Each dimension is constructed from multiple underlying indicators. To dissect the specific channels through which DVC empowers the mediator, we also utilize three secondary indicators from the index system that are particularly relevant to e-commerce functionality: the Digital Finance Index (Digfin), the Digital Cultural Tourism Index (Digctgh), and the Digital Marketing Index (Digmark).

3.1.3 Mediating Variable: Rural E-commerce (Rural e-com).

The number of Taobao Villages officially identified within a county serves as the proxy variable for the development level and cluster strength of rural e-commerce. A "Taobao Village" is defined as a village where over 10% of households operate online stores on the Taobao platform and the annual e-commerce transaction volume exceeds 10 million RMB. This metric is widely used in the literature as it captures a threshold of vibrant, grassroots e-commerce activity and represents a tangible spatial cluster phenomenon born from the "Internet plus village economy" model.

3.1.4 Control Variables.

To mitigate potential omitted variable bias and isolate the net effect of DVC, four county-level control variables are included:

1. County economic dependence on traditional agriculture (depend): Measured as the share of primary agricultural output value in the county's total GDP. A higher value indicates a greater reliance on a traditional, and potentially less diversified, mono-agricultural economic structure, which may influence the capacity and approach for ACT integration.

2. County economic density (dense): Calculated as the county's GDP divided by its total administrative land area (in square kilometers). This measures the spatial concentration and land-use efficiency of economic activity, which can be related to infrastructure quality, market access, and agglomeration effects relevant for integrated development.

3. Human capital level (graduation): Proxied by the proportion of the rural population with a senior high school education or above. This provides a basic measure of the educational attainment of the local workforce, which can affect the adoption of

digital tools and the quality of service in the tourism and culture sectors.

4. Government intervention degree (gov): Measured by the ratio of local general budgetary expenditure to regional GDP. This reflects the scale of government fiscal activity relative to the local economy, indicating the depth of government involvement and potential support for public goods, infrastructure, and industrial policies that could affect DVC and ACT integration.

3.1.5 Instrumental Variable.

To address potential endogeneity concerns (e.g., reverse causality where areas with thriving ACT industries might invest more in digitalization), we employ an instrumental variable (IV) approach. The spherical distance (in kilometers) from each county's administrative seat to the center of Hangzhou city is used as an instrumental variable (tool) for digital village development. The rationale is twofold, satisfying the key IV conditions: **Relevance:** Hangzhou is the headquarters of the Alibaba Group, a global pioneer in e-commerce, digital payments (Alipay), and cloud computing. Proximity to this epicenter of China's digital economy is plausibly correlated with greater exposure to, demonstration effects from, and early adoption of digital infrastructure, platforms, and applications, leading to higher DVC index scores. **Exclusion Restriction:** As a historical geographical variable determined by location, the distance to Hangzhou is unlikely to have a direct effect on a county's current level of ACT integration, except through its influence on digital development pathways. It is arguably exogenous to contemporary local industrial fusion outcomes, once other controlled factors are accounted for.

3.2 Empirical Models

Baseline Regression Model. To test hypotheses H1 and H2 regarding the direct effect and dimensional impacts of DVC, we estimate the following ordinary least squares (OLS) model:

$$\text{Integration}_j=\alpha_0+\alpha_1 \text{Dc}_j+\gamma Z_j+\varepsilon_j \quad (1)$$

where Integration_{ij} denotes the ACT integration score for county j in province i; Dc_j is the aggregate Digital Village Index for county j; Z_{ij} is the vector of

the four control variables described above; and ε_{ij} is the idiosyncratic error term. A positive and statistically significant α_1 would support H1. To test H2, we estimate separate regressions replacing the aggregate Dc_j with each of its four sub-dimension indices (infra, life, eco, admin) while keeping the same set of controls.

Mediation Effect Model. To test hypothesis H3 concerning the mediating role of rural e-commerce, we adopt the well-established causal steps approach (Baron & Kenny, 1986) and estimate the following system of equations:

$$\text{RuralEcom}_j = \beta_0 + \beta_1 \text{DC}_j + \gamma \mathbf{Z}_j + \varepsilon_j \quad (2)$$

$$\text{Integration}_j = \omega_0 + \omega_1 \text{RuralEcom}_j + \omega_2 \text{DC}_j + \gamma \mathbf{Z}_j + \varepsilon_j \quad (3)$$

Evidence for mediation exists if: (a) β_1 in Equation (2) is significant (DVC affects the mediator), and (b) ω_1 in Equation (3) is significant (the mediator affects the outcome after controlling for DVC). A full mediation is suggested if ω_2 becomes insignificant, while partial mediation is indicated if ω_2 remains significant but its magnitude is reduced compared to α_1 in Equation (1). To further investigate the specific empowerment pathways, we run modified versions of Equations (2) and (3), substituting the aggregate Dc_j with the specific secondary indices (Digfin, Digctgh, Digmark) that conceptually align with the financing, talent or technology, and marketing channels, respectively. We complement this analysis with formal Sobel tests to assess the statistical significance of the indirect effects ($\beta_1 \times \omega_1$).

4 Results

4.1 Descriptive Statistics and Regional Patterns

Table 2 presents the descriptive statistics for all key variables used in the analysis. The results reveal substantial variation across the 225 sample counties. The ACT integration score (Integration) has a mean of 0.204 with a standard deviation of 0.384, and ranges from -0.530 to 1.690, confirming significant disparities in integration levels. The aggregate Digital Village Index (Dc) also shows variation, with a mean of 4.236 (on a log scale) and a standard deviation of 0.195. Among its sub-dimensions, infrastructure digitization (infra) has the highest average score (92.13), while governance digitization (admin) has the lowest (55.53), indicating uneven progress

across different aspects of DVC. The mediating variable, the number of Taobao Villages (Rural e-com), averages 1.22 per county but ranges from 0 to over 6, highlighting the clustered and uneven nature of e-commerce development. The control variables also exhibit expected variation, reflecting the diverse economic structures and conditions across the Yangtze River Delta.

Table 2 Descriptive statistical results

Variable Category	Variable Name	Obs	Mean	Std. Dev.	Min	Max
Dependent Variable	integration	225	0.204	0.384	-0.530	1.690
Explanatory Variable	Dc	225	4.236	0.195	3.870	4.805
	infra	225	92.13	10.97	73.09	118.8
	eco	225	64.05	22.86	31.40	154.9
	admin	225	55.53	17.03	2.151	96.81
	life	225	64.31	21.60	22.61	117.1
Control Variables	depend	225	4.709	0.844	0.090	5.709
	dense	225	0.408	0.140	0.001	1.011
	graduation	225	0.021	0.028	0.001	0.292
	gov	225	0.171	0.092	0.000	0.586
Mediating Variable	Rural e-com	225	1.222	1.689	0	6.142

A spatial analysis of the ACT integration composite scores (graphically represented in the original study's Figure 4) reveals pronounced regional disparities within the region. The overall development level, while promising in pockets, clearly requires further enhancement for balanced regional growth. A clear gradient is observed: counties in Zhejiang Province generally achieve the highest integration scores, followed by those in Jiangsu Province. Counties in Anhui Province, on average, show the lowest levels of integration. Within Anhui itself, a further north-south divide is evident, with southern regions (rich in cultural and natural tourism resources like Huangshan) outperforming the more agriculturally focused northern plains, which currently lack distinctive tourism features to drive fusion. This pattern underscores the importance of underlying resource endowments and pre-existing economic conditions, which our models aim to control for.

4.2 Baseline Regression Results

The results from the baseline OLS regressions are presented in Table 3. Column (1) reports the estimation for the aggregate Digital Village Index (Dc). The coefficient for Dc is 0.633 and is statistically significant at the 1% level. This implies that, holding other factors constant, a one-unit increase in the DVC index is associated with a 0.633-unit increase in the ACT integration score. This finding provides strong empirical

support for H1, confirming that digital village construction is a significant driver of agro-cultural-tourism integration.

The control variables yield insightful results. The coefficient for depend is negative (-0.004) and statistically significant ($p<0.05$), suggesting that counties with economies more heavily reliant on traditional, primary agriculture tend to have lower levels of ACT integration. This is plausible, as such a structure may indicate less economic diversification, weaker linkages to service sectors like tourism, and potentially a mindset less oriented towards the innovative fusion required for ACT development. Conversely, edense (economic density) shows a significant positive coefficient (0.007, $p<0.01$). Higher economic density likely facilitates integration through several channels: it often correlates with better infrastructure, larger local markets, more frequent knowledge spillovers, and a thicker market for specialized services, all of which can be leveraged by digital tools to lower transaction costs and create new synergies. The coefficient for graduation is negative (-0.089, $p<0.01$) and significant. This seemingly counterintuitive result may be explained by selective migration: individuals with higher education from rural counties are more likely to migrate to cities for better employment opportunities, leaving a potential gap in high-skilled human capital locally. Furthermore, the general rural population's digital literacy might still be a constraint; without targeted skills, digital tools may not be fully harnessed for integration. Finally, gov (government intervention) has a large, positive, and highly significant coefficient (1.216, $p<0.01$). This underscores the critical, perhaps indispensable, role of proactive local government support through fiscal expenditure. Such spending likely funds essential public goods, infrastructure, promotional activities, and supportive policies that create the initial conditions and continuing momentum for successful ACT integration projects.

Columns (2) through (5) in Table 3 display the results when the aggregate DVC index is disaggregated into its four core dimensions. All four coefficients are positive and statistically significant at the 1% level, providing clear support for H2. The magnitude of the coefficients, however, reveals a distinct hierarchy of influence on ACT integration: infrastructure digitization (infra, coef. = 0.011) has the largest estimated effect, followed by life digitization (life, coef. = 0.005), then economic digitization (eco, coef. = 0.004), and finally governance digitization (admin, coef. = 0.002). This ranking suggests a logical sequence in the digital empowerment process. Foundational digital infrastructure (broadband, networks, data centers) appears to be the most potent direct enabler, providing the essential "plumbing" upon which all other digital applications

depend. The digitization of life services, which enhances the quality and attractiveness of rural living for both residents and potential visitors, emerges as the next most influential driver. While economic digitization directly targets production and business processes, its impact on the complex outcome of integration might be more specialized or require complementary investments. Governance digitization, though beneficial for creating a transparent and efficient environment, seems to have the most indirect and long-term effect on industrial fusion in this cross-sectional snapshot.

Table 3 Baseline Regression and Sub-dimension Results

Variable	(1)integration	(2)integration	(3)integration	(4)integration	(5)integration
Dc	0.633***				
	(0.137)				
infra		0.011***			
		(0.002)			
eco			0.004***		
			(0.001)		
admin				0.002***	
				(0.000)	
life					0.005***
					(0.001)
depend	-0.004**	-0.007***	-0.004**	-0.004**	-0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
edense	0.007***	0.008***	0.009***	0.009***	0.007***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
graduation	-0.089***	-0.137***	-0.086***	-0.069***	-0.062***
	(0.021)	(0.024)	(0.021)	(0.021)	(0.022)
gov	1.216***	1.114***	1.305***	1.341***	0.954***
	(0.239)	(0.248)	(0.260)	(0.259)	(0.239)
Constant	-2.291***	-0.028	-0.064	-0.042	-0.119
	(0.583)	(0.274)	(0.272)	(0.264)	(0.274)
Observations	225	225	225	225	225
R-squared	0.364	0.354	0.346	0.368	0.344

Note: Standard errors in parentheses are clustered at the county level; *** p<0.01, ** p<0.05, * p<0.1

4.3 Mediation Effect Results

The mediation analysis results, testing H3, are detailed in Table 4. Columns (1), (3), and (5) present the first-stage regressions (Equation 2) where the specific DVC empowerment indices are used to predict the mediator, rural e-commerce (Rural e-com). The coefficients for Digfin (0.045), Digctgh (1.053), and Digmark (2.359) are all positive and statistically significant at the 1% level. This confirms that advancements in digital finance, digital cultural tourism, and digital marketing capabilities are strongly associated with the growth of Taobao Villages and rural e-commerce activity.

Table 4. Mediation Analysis: The Role of Rural E-commerce

Variable	(1)Digfin Path		(2)Digctgh Path		(3)Digmark Path	
	Rural e-com	integration	Rural e-com	integration	Rural e-com	integration
Digfin	**0.045*** **	0.002***				
	(0.007)	(0.001)				
Digctgh			1.053***	0.072***		
			(0.353)	(0.021)		
Digmark					2.359***	0.242***
					(0.725)	(0.050)
Rural e-com		0.073***		0.077***		0.084***
		(0.005)		(0.004)		(0.005)
depend	**-0.023*** **	0.001**	-0.025***	0.001**	-0.025***	0.002***
	(0.009)	(0.001)	(0.009)	(0.001)	(0.009)	(0.001)
edense	0.020***	0.003***	0.028***	0.003***	-0.055	0.046***
	(0.006)	(0.001)	(0.008)	(0.001)	(0.152)	(0.010)
graduation	-0.828***	0.001	-0.158	0.035***	-5.241	-0.110
	(0.145)	(0.011)	(0.116)	(0.008)	(3.195)	(0.174)
gov	-1.955**	-0.075	-2.387**	-0.117	24.066*	1.068**
	(0.946)	(0.081)	(1.069)	(0.085)	(12.442)	(0.462)
Sobel Test		0.003*		0.081*		0.198*
Z-statistic		6.158		3.323		3.263
Constant	2.786**	3.559***	2.952**	3.551***	2.595*	3.533***
	(1.338)	(0.092)	(1.317)	(0.093)	(1.568)	**(0.100)**
Observations	225	225	225	225	225	222
R-squared	0.325	0.751	0.226	0.746	0.164	0.707

Note: Clustered robust standard errors are shown in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Columns (2), (4), and (6) present the second-stage regressions (Equation 3). In all three models, after including the respective DVC dimension index as a control, the coefficient for the mediator Rural e-com remains positive and highly significant (coefficients of 0.073, 0.077, and 0.084, all $p<0.01$). This indicates that rural e-commerce development has a strong, independent positive association with ACT integration, even after accounting for the direct effects of the digital empowerment factors. Crucially, the Sobel test statistics reported at the bottom of the relevant columns are all significant at the 1% level (Z-values of 6.158, 3.323, and 3.263). This formal test confirms that the indirect pathways from DVC through rural e-commerce to ACT integration are statistically significant.

These results robustly support H3 and illuminate three distinct, empirically validated mediation pathways:

1. **The Digital Finance Pathway:** Improvements in the Digital Finance Index facilitate better access to capital for rural e-commerce entrepreneurs (e.g., through fintech credit models). This financial empowerment allows e-commerce businesses to scale, invest in product quality, and market development, which in turn fuels ACT integration projects in their localities. The estimated indirect effect for this pathway is

0.003.

2. **The Digital Cultural Tourism Pathway:** Growth in the Digital Cultural Tourism Index signifies greater online visibility and engagement with local culture and tourism assets. This attracts talent (content creators, tour operators) and introduces relevant technologies to the rural e-commerce space. E-commerce platforms, infused with this cultural-tourism content and expertise, then become more effective channels for marketing integrated experiences (e.g., selling a food product alongside a virtual tour of its place of origin). The indirect effect for this pathway is larger, at 0.081.

3. **The Digital Marketing Pathway:** A higher Digital Marketing Index reflects stronger capabilities in online promotion and customer reach. This directly channels consumer traffic and market demand to rural e-commerce platforms. The resulting market pull incentivizes e-commerce sellers and their supply chains to upgrade, standardize, and brand their offerings, which are fundamental processes for creating market-ready, high-value ACT products. This pathway shows the largest indirect effect of 0.198.

In summary, the findings reveal that DVC promotes ACT integration not only through direct channels (as per H1 and H2) but also, and substantially, by first empowering a vibrant rural e-commerce sector. This e-commerce sector then acts as a powerful agent of integration by mobilizing capital (finance pathway), attracting and applying knowledge (cultural-tourism pathway), and connecting directly with market demand (marketing pathway).

4.4 Endogeneity and Robustness Checks

To address concerns that the observed relationship between DVC and ACT integration might be driven by unobserved confounding factors or reverse causality, we performed a Two-Stage Least Squares (2SLS) estimation using the instrumental variable described earlier. The results are presented in Table 5. The first-stage regression shows that the instrument, distance to Hangzhou, has a negative and highly significant effect on the DVC index (coefficient = -0.0005, $p<0.01$), confirming the relevance condition. The first-stage F-statistic is 35.82, well above the common threshold of 10, allowing us to reject the hypothesis of a weak instrument. In the second stage, the coefficient on the instrumented DVC variable remains positive and significant (2.285, $p<0.01$). Notably, this 2SLS estimate is larger than the OLS estimate from Table 3, column (1). While the magnitude difference warrants caution in

interpretation, the key conclusion is that the positive effect of DVC on ACT integration remains statistically significant and robust after attempting to control for endogeneity, strengthening our confidence in a causal interpretation.

Table 5. Instrumental Variable Analysis for Endogeneity

Variable	Dependent Variable		
	(1)OLS Integration	(2)First Stage Dc	(3)Second Stage Integration
Dc	0.633***		2.2847***
	(0.138)		(-0.425)
tool		-0.0005*	
		(0.000)	
Constant		4.3821***	-9.6778***
		(0.027)	(1.802)
Observations	225	225	225
R-squared		0.138	
First-stage F-stat		35.82	

Note: Clustered robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

We conducted several additional robustness checks to ensure the stability of our core findings, summarized in Table 6. First, we constructed a constrained dataset by removing outliers: we excluded counties from Hangzhou (the source of the IV) and then trimmed the top and bottom 5% of counties based on the DVC index. Re-running the baseline regression on this reduced sample (n=196) yielded a coefficient for Dc of 0.835 ($p<0.01$), consistent with the main result. Second, we altered the construction of the dependent variable by recalculating the ACT integration score using the entropy weight method instead of factor analysis to assign weights to the 14 indicators. The regression using this alternative measure produced a significant positive coefficient of 0.329 ($p<0.01$) for Dc. Third, to partially account for dynamic effects and mitigate simultaneous causality, we used a one-period lag of the key variables where possible. The lagged regression also showed a significant positive effect (coefficient = 0.966, $p<0.01$). Across all these alternative specifications and tests, the central finding that digital village construction significantly promotes agro-cultural-tourism integration proves to be highly robust.

Table 6. Robustness Check Results

Variables	(1) Constrained Dataset integration	(2) Adjusted Dep. Var. integration	(3) Lagged Dep. Var. integration
Dc	0.835***	0.329***	0.966***
	-0.145	-0.049	-0.121
Constant	-3.338***	-0.732***	-4.029***
	-0.716	-0.259	-0.642
Observations	196	225	222
R-squared	0.25	0.259	0.342
F-statistic	12.69	15.33	13.86

Notes:Cluster-robust standard errors in parentheses. *** p<0.01,** p<0.05,* p<0.1. Control variables are included but not shown. (1) Excludes Hangzhou and extreme DVC values. (2) Uses entropy method for dependent variable weights. (3) Uses lagged dependent variable.

5 Discussion

5.1 Theoretical Implications

This study makes several substantive contributions to the intersecting literatures on digital transformation, rural development, and industrial integration. First, it moves decisively beyond the prevalent scholarly trend of examining digitalization, platform economies, and rural industry fusion in isolation or through simple pairwise links. By constructing, articulating, and empirically validating an integrated "Digital Foundation to E-commerce Platform to Industry Integration" framework, we offer a more holistic, mechanistic, and sequential understanding of how digital transformation catalyzes complex rural socio-economic restructuring. The identification and validation of rural e-commerce as a critical transmission hub and effect amplifier clarifies a pivotal but previously underspecified linkage in this process. This directly addresses growing calls in the literature for research that delineates the specific, operational pathways through which digital infrastructure translates into tangible and sustainable industrial outcomes in rural settings (Yang & Ning, 2025).

Second, the discovery of differential direct impacts across the four DVC dimensions provides nuanced theoretical insights into the layered nature of digital rural transformation. The finding that infrastructure and life digitization exert the strongest direct influence suggests a potential sequence of priorities: during the early or intermediate phases of building a digital countryside, establishing a robust "digital base" (physical and network infrastructure) and enhancing the quality of digital life to improve livability and attract human capital are paramount for enabling broader industrial synergy. The relatively more modest direct effects of economic and

governance digitization in our cross-sectional model imply that their benefits for a complex outcome like ACT integration might be more contingent upon the prior or parallel establishment of basic digital connectivity and user adoption. Alternatively, their influence may be more effectively channeled and realized through specific intermediary agents and market processes, such as the e-commerce platforms highlighted in our mediation analysis. This observation aligns with and usefully extends theoretical perspectives emphasizing the sequential, ecosystem-dependent, and often non-linear nature of digital value creation(Wulfert et al., 2024).

Third, the delineation and empirical verification of the tripartite mediation pathways (financing, talent or technology, marketing) through e-commerce significantly advances our understanding of the micro-mechanisms of digital empowerment. It responds directly to identified gaps regarding how e-commerce platforms specifically operationalize the conversion of local, often tacit, resources (agricultural products, cultural heritage, landscape beauty) into marketable commodities, compelling experiences, and valuable brands (Kusumastuti et al., 2024). Our findings demonstrate that e-commerce's role is not monolithic but multifaceted: it functions simultaneously as a financial intermediary (mitigating credit constraints), a talent aggregator and innovation catalyst (attracting skills and new ideas), and a market-maker and signal transmitter (connecting supply with demand and communicating quality standards). This refined conceptualization provides a more granular framework for future research on platform-driven rural development.

5.2 Practical Implications

The findings yield concrete, actionable implications for policymakers and practitioners engaged in rural revitalization and digital strategy.

First, DVC strategies must be sophisticated, differentiated, and sequentially prioritized. Given the paramount direct effect of infrastructure digitization, continued and targeted public investment in next-generation information infrastructure (e.g., 5G, fiber-optic broadband, IoT sensors) and the concomitant digital upgrading of financial service access points in rural areas remain essential. This is the non-negotiable "digital bedrock" required to ensure that digital dividends reliably reach the "last mile." Concurrently, based on the differential impacts observed, a synergistic, multi-pronged strategy is warranted. While consolidating infrastructure advantages, significant policy and entrepreneurial effort should be directed toward developing attractive digital life

services and content. This includes fostering digital cultural tourism platforms, promoting smart wellness applications, and expanding access to online education and telemedicine. These enhancements directly improve rural livability for residents and increase the allure for tourists and potential new residents, thereby stimulating demand for integrated offerings. For the dimensions of economic and governance digitization, which showed significant but relatively smaller direct effects in our model, policy should focus on enabling and incentivizing the digital transformation of the entire agricultural value chain, ranging from smart farming and traceability systems to digital logistics and automated processing. Furthermore, promoting the use of digital technologies to build transparent monitoring, evaluation, and feedback systems for ACT integration initiatives can greatly enhance the scientific basis, accountability, and adaptive efficacy of public governance and decision-making in this domain.

Second, the "mediating hub" function of rural e-commerce must be intentionally reinforced through integrated policies that foster a "Digital Finance plus E-commerce Platform plus Industrial Cluster" linkage model. This involves interventions on three fronts:

1. **Deepening financial innovation:** Policymakers should encourage and facilitate deeper collaboration between commercial banks, fintech firms, and major e-commerce platforms. The goal is to develop and scale innovative credit assessment models that leverage the rich, real-time transaction, logistics, and reputational data generated on e-commerce platforms. This can unlock supply chain financial products like "e-commerce loans," "invoice financing," and "order-based advances" tailored for small-scale ACT entrepreneurs. Concurrently, the operations of e-commerce-affiliated microcredit companies should be appropriately regulated to ensure stability and consumer protection, while tripartite cooperation among banks, local governments, and platform enterprises should be strengthened to co-develop intelligent decision-support systems for e-commerce supply chains serving the ACT sector.

2. **Implementing targeted talent strategies:** National and local "Digital Commerce Revitalizes Agriculture" talent programs should be vigorously implemented. These programs should offer structured support, such as startup subsidies, advanced digital skills training, mentorship, and direct platform resource linkages, to attract and retain “new farmers,” particularly returning entrepreneurial youth and digitally skilled urban migrants. These actors are crucial for leveraging e-commerce tools and new media marketing concepts to creatively interpret, package, and communicate local cultural resources, thereby building distinctive local industrial identities and brands

(often summarized as the "one village, one product; one town, one industry" model).

3. **Supporting marketing innovation and brand building:** Local governments should actively partner with e-commerce and social media platforms to co-create innovative marketing campaigns. This includes supporting live-streaming sales events, "content seeding" by influencers, and short-video challenges that highlight local ACT products and experiences. A key objective should be to help build and manage strong county-level or regional public brands for ACT offerings. This market-driven, visibility-enhancing approach creates powerful incentives that compel upstream supply chains to standardize, certify, and upgrade product quality. It effectively reduces information asymmetry between rural producers and distant consumers, and significantly expands the market radius and customer base for integrated ACT products.

Third, successful ACT integration demands adherence to the principles of local adaptation and systematic, cross-sectoral integration. Local governments must resist the temptation of "one-size-fits-all" templates or homogeneous competition. Instead, they should formulate differentiated ACT integration master plans based on a clear-eyed assessment of core local comparative advantages. These may include unique cultural heritage, distinctive agricultural products, or exceptional natural landscapes, as identified through diagnostic tools such as the factor analysis applied in this study. Regions rich in intangible cultural heritage should focus strategic investments on the digital preservation, archiving, and creative revitalization of those assets. Areas with distinctive agricultural products (e.g., geographical indications) should concentrate on digital brand building, quality assurance systems, and industrial chain extension into processing and experiential tourism. Critically, achieving this requires breaking down entrenched administrative silos. A cross-sectoral collaborative governance mechanism involving departments of agriculture, culture and tourism, industry and information technology, finance, and science and technology is essential to ensure the alignment of plans, policies, funding streams, and pilot projects. Practical measures could include establishing special public-private partnership funds for ACT integrated development and constructing physical or virtual "cross-boundary industry parks" that co-locate or network businesses from the different sectors. Such initiatives can facilitate the free flow and efficient re-combination of capital, talent, data, and ideas, generating a synergistic industrial effect where the integrated whole becomes greater than the sum of its separate parts. This is the pathway to realizing genuinely diversified, resilient, and sustainable rural economic prosperity in the digital age.

5.3 Limitations and Future Research

While this study provides robust evidence for the proposed integration mechanism, it is subject to several limitations that point toward fruitful avenues for future research. First, the reliance on cross-sectional data for the year 2020 restricts our ability to make strong claims about long-term dynamic effects, establish the precise timing of impacts, or fully rule out all forms of endogeneity. Future research would greatly benefit from employing panel datasets that track counties over multiple years. This would allow for the use of more dynamic models, fixed effects to control for time-invariant county heterogeneity, and better analysis of the evolution and persistence of the observed relationships.

Second, the empirical context is the Yangtze River Delta, one of China's most economically developed and digitally advanced regions. The specific magnitudes of the effects and the precise configuration of the mechanism might differ in less developed central, western, or northeastern regions of China, which have different resource endowments, institutional capacities, and market structures. Comparative studies across regions with varying levels of development, or international comparative studies, are warranted to test the generalizability and boundary conditions of our framework.

Third, while the number of Taobao Villages is a well-established and meaningful proxy for vibrant, grassroots e-commerce activity, it is an imperfect measure. It does not capture transaction volumes, the diversity of platforms used (e.g., Pinduoduo, JD.com, TikTok), or the value-added nature of the e-commerce activities. Future studies could incorporate more nuanced and continuous metrics, such as county-level e-commerce sales turnover, the number of active online stores, or the penetration rate of electronic payments, to provide a richer and more granular picture of the rural e-commerce ecosystem.

Finally, our analysis is conducted at the county level, which is appropriate for policy-oriented analysis. However, the actual processes of integration, entrepreneurial decision-making, and community engagement happen at the micro-level, such as in villages, cooperatives, and individual firms. Future research employing mixed methods, such as case studies, surveys, or in-depth interviews with entrepreneurs, local officials, and residents in selected Taobao Villages or ACT integration demonstration sites, could offer invaluable qualitative insights. This would help illuminate the on-the-ground challenges, social dynamics, learning processes, and unintended consequences that accompany digital-powered ACT integration, thereby complementing the macro-

picture painted by quantitative studies like this one.

6 Conclusion

This study empirically investigates the mechanism through which digital village construction promotes agro-cultural-tourism integration, with a particular focus on the indispensable mediating role of rural e-commerce. Based on a comprehensive analysis of cross-sectional data from 225 counties in China's Yangtze River Delta, the findings confirm that DVC is a powerful and significant driver of ACT integration. This influence operates through dual channels: a direct effect and a substantial indirect effect mediated by a thriving rural e-commerce sector.

The direct effect is most potent for the digitization of infrastructure and rural life, suggesting these are foundational priorities. Crucially, rural e-commerce acts as the vital transmission belt in this system. DVC empowers e-commerce through specific advancements in digital finance, digital cultural tourism, and digital marketing capabilities. This empowered e-commerce sector, in turn, becomes a direct agent of integration by mobilizing essential capital (solving financing constraints), attracting and applying relevant talent and technology (fostering innovation), and efficiently connecting local supply with latent market demand (enhancing market access and signaling).

The study elucidates a clear and actionable sequential pathway: strategic investment in digital infrastructure and services creates the enabling environment. This environment catalyzes the activation and growth of rural e-commerce platforms. These platforms then become the engines that drive the deep, market-oriented integration of agricultural production, cultural expression, and tourism experiences. For policymakers, this implies a necessity for coherent, layered strategies: continued investment in universal digital foundations, targeted support to cultivate a multifunctional and inclusive e-commerce ecosystem, and place-based, participatory planning for ACT integration that leverages local distinctiveness. By understanding, respecting, and strategically leveraging this integrative mechanism, the vast potential of digitalization can be more effectively harnessed as a reliable engine for building sustainable, prosperous, and vibrant rural futures in China and beyond.

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Generative AI statement

AI-assisted translation was used to convert the initial Chinese draft of this manuscript into English. The author(s) have thoroughly reviewed, substantively revised, and validated the translated text. The author(s) are ultimately accountable for all aspects of the work, including its academic rigor and factual correctness.

Data availability

The original contributions presented in the study are included in the article/Supplementary Material , further inquiries can be directed to the corresponding author/s.

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Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

Informed Consent

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