frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 13 January 2026
DOI 10.3389/fsufs.2025.1751812

OPEN ACCESS

EDITED BY
Fuyou Guo,
Qufu Normal University, China

REVIEWED BY
Jie Wen,
Hunan University of Finance and Economics, China
Hai Li,
Hunan Women's University, China

*CORRESPONDENCE
Jingjing Wang
✉ wjj2111987@163.com

RECEIVED 22 November 2025
REVISED 23 December 2025
ACCEPTED 26 December 2025
PUBLISHED 13 January 2026

CITATION
Li T and Wang J (2026) The impact and mechanism of the digital economy on the high-quality development of agriculture and tourism integration—based on data from 30 provinces in China from 2012 to 2023. *Front. Sustain. Food Syst.* 9:1751812. doi: 10.3389/fsufs.2025.1751812

The impact and mechanism of the digital economy on the high-quality development of agriculture and tourism integration—based on data from 30 provinces in China from 2012 to 2023

Tianqi Li and Jingjing Wang*

Business Department, Hunan University of Humanity, Science and Technology, Loudi, China

The digital economy deeply penetrates the process of agriculture and tourism integration through core resources such as digital network information, traffic, technology, and platforms, optimizes resource allocation and operation models, and drives the realization of efficient collaboration and high-quality development in agriculture and tourism integration. Based on the analysis of the mechanism of the impact of the digital economy on the high-quality development of agriculture and tourism integration, using panel data from 30 provinces in China from 2012 to 2023 as samples, the ordinary panel regression model, the mediation effect model and the threshold effect model were conducted to verify the intrinsic relationship between the digital economy and the high-quality development of agriculture and tourism integration. Results show that the digital economy has a significant promoting effect on the high-quality development of agriculture and tourism integration. In regions with different agricultural resource bases and cultural resource endowments, the enabling effect of the digital economy on the high-quality development of agriculture and tourism integration varies, and this effect is stronger in regions with high agricultural resource bases and high cultural resource endowments. The digital economy promotes the high-quality development of agriculture and tourism integration through reducing operational costs, optimizing industrial structure, and improving public services. Through further analysis, it is found that the impact of the digital economy on the high-quality development of agriculture and tourism integration has a dual threshold effect with itself, that is, as the level of the digital economy increases, its positive impact on the high-quality development of agriculture and tourism integration becomes significant from insignificant, and gradually weakens after crossing the second threshold value.

KEYWORDS

agriculture and tourism integration, digital economy, high-quality development, mediation effect, threshold effect

1 Introduction

Under the background of continuous economic transformation and upgrading, the digital economy has developed into the core engine driving the transformation and upgrading of various industries. Based on the new generation of digital economy such as 5G communication, big data analysis and artificial intelligence, and relying on digital platforms to carry out

innovative practices, this has created unprecedented development opportunities for cross-industry deep integration (Zhao et al., 2022). Through the in-depth penetration and innovative application of the digital economy, the phenomenon of information silos among traditional industries has gradually been eliminated, and significant synergy effects have been formed in aspects such as the circulation of data elements and the optimization of resource allocation (Lu et al., 2024). This technological empowerment not only reconfigures the industrial value chain but also gives rise to a cross-disciplinary model of integrated innovation, promoting different industrial entities to build an open, shared, mutually beneficial and symbiotic digital ecosystem. In recent years, countries around the world have prioritized data and the digital economy as key directions and strategic priorities. For instance, Germany has launched the "Digital Strategy," aiming to promote the construction of digital infrastructure, facilitate innovation and the development of the digital industry (Bukht and Heeks, 2018).

In recent years, China has attached great importance to the digital transformation of industries and has established a systematic policy support system. The report of the 20th National Congress of the Communist Party of China proposes to accelerate the development of the digital economy, promote the deep integration of the digital economy and the real economy, and build digital industrial clusters with international competitiveness (Zhao et al., 2022). The 2025 government work report of China emphasizes stimulating the innovative vitality of the digital economy, continuously promoting the "Artificial Intelligence Plus" initiative, better integrating the digital economy with manufacturing and market advantages, promoting the standardized and healthy development of the platform economy, and better leveraging its positive role in promoting innovation, expanding consumption, and stabilizing employment (Ye, 2025).

The integration of agriculture and tourism is a new type of industrial development model formed by the deep combination of agricultural industry and tourism activities through resource integration, functional superposition and business model innovation (Wang and Zhou, 2021). The early integration of agriculture and tourism was mainly manifested in the forms of rural tourism, agricultural tourism and leisure sightseeing agriculture. The "Citizens' garden" that emerged in Germany in 1850 was the earliest case of the integrated development of agriculture and tourism (Kaswanto, 2015). Subsequently, many countries have successively adopted policy support to guide the integrated development of agriculture and tourism. Scholars believe that the integration of agriculture and tourism will not only give rise to new market spaces and consumer demands, but also promote the high quality of tourism and agricultural products (Pillay and Rogerson, 2013; Streifeneder, 2016). Meanwhile, the integrated development of agriculture and tourism is conducive to addressing some local issues, such as the shortage of labor in the tourism industry and the insufficient market demand for agricultural products (Rogerson, 2012; Pitrova et al., 2020). The development of agricultural tourism can provide economic incentives and stable guarantees for farmers, improve the quality of life of rural residents in mountainous areas, and is also conducive to strengthening the connection between urban and rural areas and promoting the protection of natural or cultural heritage (Tew and Barbieri, 2012). The integration of agriculture and tourism in China has gone through the stages of traditional farmhouses and sightseeing agriculture, agricultural experience activities, ecological agriculture, characteristic agriculture and leisure vacations. Currently, it is gradually moving towards the digital and intelligent stage, developing in depth from simplicity to complexity, from singularity to diversity, and from tradition to modernity. Chinese scholars have mainly focused on the internal mechanism, dynamic elements, and measurement of integration levels of agriculture and tourism integration, and have demonstrated its promoting effect on rural revitalization and the coupling and coordination degree with rural revitalization (Luo and Wu, 2022; Wang et al., 2023). However, current research mostly focuses on the integration of agriculture and tourism itself, such as how the two industries are integrated and the driving factors behind the integration, and little attention has been paid to the level measurement and driving factors of high-quality development of such integration.

The mechanism of the digital economy's impact on the integration of agriculture and tourism is mainly achieved through the process of "penetration - reconstruction - redefinition" (Chang et al., 2019; Pitrova et al., 2020a), and is advanced in an orderly manner relying on the four-dimensional path system of "integration—innovation—diffusion—optimization," thereby achieving the high-quality development goal of industrial integration (Khairabadi et al., 2020). Promoted by the digital economy, the integrated development of agriculture and tourism has broken through the traditional simple superposition model of agriculture and tourism, evolving into a new industrial form driven by industrial integration and featuring multi-functional and sustainable development (Ayyildiz and Koc, 2024). This evolution process is achieved through the empowerment of technological innovation and the reorganization of resource elements. Promote the realization of multiple goals such as the establishment of ecological protection mechanisms, the dynamic inheritance of local culture, and rural revitalization. Under the background of the new era, exploring the impact of the digital economy on the integrated development of agriculture and tourism helps to understand and grasp the new opportunities for the integrated development of agriculture and tourism, thereby promoting the high-quality development of the integrated development of agriculture and tourism. For this reason, researchers has actively explored the relationship between the digital economy and the tourism industry, as well as between the digital economy and the agricultural tourism industry (Collins et al., 2024). The digital economy, as a knowledge-intensive "clean" production factor, has been widely adopted by manufacturing enterprises in their production and operation processes, playing a crucial role in reducing costs, enhancing efficiency, promoting innovation, and optimizing performance (Ma and Zhang, 2025). At the same time, it injects new elements, models, new business forms and new commercial patterns into the industrial chain development, leading the industrial chain to achieve transformation and upgrading. In the field of cultural and tourism integration, the enabling mechanism of the digital economy mainly focuses on resource allocation, virtual integration and innovation diffusion (Huang J. et al., 2025; Huang M. et al., 2025). The digital economy can promote the high-quality development of the tourism industry by reducing operating costs, upgrading the industrial structure level and improving public services (Jiang and Murmann, 2022), and helps promote the integration of resources in the agricultural and tourism industries, while its effect has a spatial effect (Shen and Hu, 2024). However, there has been insufficient in-depth exploration of the mechanism by which the digital economy contributes to the integration of agriculture and tourism. Moreover, there is relatively less attention paid to its role in promoting the high-quality development of the integration of agriculture and tourism.

Existing research has laid a foundation for this study, but it still needs to be further deepened: Current research mostly focuses on the integration of agriculture and tourism itself, and there are relatively few systematic research focuses on the high-quality development of the integration of agriculture and tourism, especially from the perspective of the digital economy' impact. Most of the existing studies focus on digital governance and risk prevention in the integration of agriculture and tourism empowered by the digital economy, as well as the new business forms and new paths of digital cultural tourism. However, there are still deficiencies in the research on the mechanism of digital economy empowering the integration of agriculture and tourism from an empirical analysis perspective.

Researches showed that the digital economy can effectively promote industrial integration. But can it effectively promote the high-quality development of agriculture and tourism integration? What are the theoretical connections between the digital economy and the high-quality development of agriculture and tourism integration? What are the characteristics of the impact of the digital economy on the high-quality development of agriculture and tourism integration? The answers to these questions are not only the basis for deepening the theoretical system of digital economy enabling industrial integration, but also the prerequisite for accurately grasping the driving mechanism of the high-quality development of agriculture and tourism integration and solving the current digital transformation problems in the process of agriculture and tourism integration. This study intends to take the interactive relationship between the digital economy and the high-quality development of agriculture and tourism integration as the main line, and through the combination of theoretical deduction and empirical analysis, systematically explain the intrinsic theoretical connection between the two, reveal the mechanism by which the digital economy affects the high-quality development of agriculture and tourism integration, and further explore its action path and practical strategies, in order to provide solid theoretical support and scientific decision-making references for promoting the deep integration of the digital economy and agriculture and tourism integration and facilitating rural industrial revitalization and high-quality development.

The marginal contributions of this paper are as follows: ① Existing studies mostly focus on the impact of the digital economy on industrial integration itself. This study, through empirical analysis, examines the impact of the digital economy on the high-quality development of agriculture and tourism integration, providing a new perspective for the high-quality development of agriculture and tourism integration and also expanding the research framework of the enabling effect of the digital economy; ② Explain the mechanism by which the digital economy affects the high-quality development of agriculture and tourism integration and test it using the mediating effect model; ③ Considering the phased characteristics of digital economy development, this study demonstrates the nonlinear impact characteristics of the digital economy on the high-quality development of agriculture and tourism integration.

2 Theoretical analysis and research hypotheses

Based on the core logic of technology penetration and resource reorganization in the theory of industrial convergence, the digital economy, supported by digital resources such as digital network information, traffic, technology and platforms, promotes the digital transformation of agriculture and tourism, achieving digital operation and high-quality development in all links (Huang J. et al., 2025; Huang M. et al., 2025). It breaks the boundaries of the production fields of the agricultural and tourism industries, reconfigures production links and factor allocation, realizes cross-border integration, and gives birth to new products, new businesses and business models that conform to the characteristics of the platform economy's bilateral market (Li and Yue, 2025; Nagle et al., 2025). It gradually penetrates into the entire industrial level. From the perspective of value chain increment, the digital economy increases the consumption added value in non-productive activities, creates new forms of value addition, and expands the industrial value chain (Ma Y. et al., 2025; Ma Z. et al., 2025). At the same time, relying on the decentralized collaboration logic of the network effect theory, it weakens the spatial dependence between enterprises and enhances the industrial collaborative connection (Huang J. et al., 2025; Huang M. et al., 2025). The digital economy not only promotes the digital transformation within the industry, but also optimizes the industrial structure and production efficiency, and extends the empowerment effect to related industries and social fields, ultimately promoting the high-quality development of agricultural and tourism integration, which is shown in Figure 1.

2.1 The direct effect of the digital economy on the high-quality development of the integration of agriculture and tourism

The direct impact of the digital economy on the high-quality development of the integration of agriculture and tourism is manifested as follows: In the short term, the digital economy provides a broad creative space and technical support for the design and development of agricultural tourism products (Wang and Mei, 2024). By applying cutting-edge technologies such as VR and AR to create immersive agricultural tourism experience projects, it enables diversified and personalized innovation of products, directly enhancing the market competitiveness of the integrated products. At the same time, dynamic monitoring is another key short-term effect. The advanced technological means such as big data analysis and Internet of Things perception possessed by the digital economy can accurately collect various data in real time during agricultural production and tourism activities, including parameters of agricultural product growth environment, tourist flow and behavioral preferences (Lapuz, 2023). Through in-depth mining and analysis of these data, it can promptly identify problems and potential opportunities in the process of agricultural tourism integration, providing scientific basis for relevant decisions and ensuring the stable and efficient advancement of integrated development (Philip and Williams, 2019). In the long term, the digital economy promotes the optimization of ecological resource allocation, accelerates the digital transformation of ecological industries, and promotes the green and sustainable development of ecological industries (Quaglione et al., 2020). At the same time, it achieves effective digital governance of agricultural pollution environment, improves the efficiency of rural environmental pollution governance, and comprehensively improves the rural living environment, thereby driving the integration of agriculture and tourism to move towards a more efficient, innovative, and sustainable

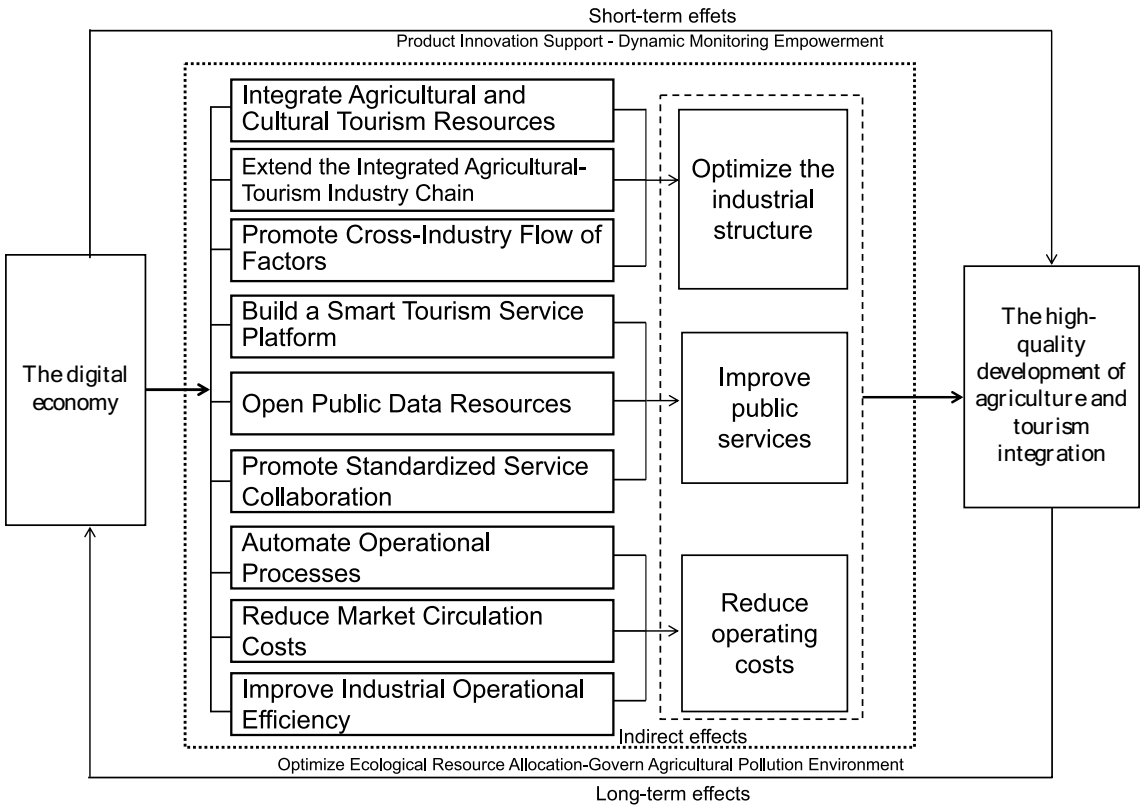

FIGURE 1
The mechanism of the digital economy on the high-quality development of agriculture and tourism integration.

high-quality development direction in the long term. In conclusion, the following hypotheses are proposed.

> Hypothesis 1: The digital economy can directly promote the high-quality development of the integration of agriculture and tourism.

2.2 The indirect effect of the digital economy on the high-quality development of the integration of agriculture and tourism

2.2.1 The digital economy promotes the high-quality development of the integration of agriculture and tourism by optimizing the industrial structure

The digital economy breaks the traditional industrial boundaries between agriculture and tourism, and promotes the systematic optimization of the industrial structure through digital technology as a link, achieving high-quality development of the integration of agriculture and tourism (Liu et al., 2024). Specifically, the digital economy integrates resources such as agricultural production, rural culture, and ecological landscapes through technologies like big data and the Internet of Things, and builds an integrated business system of "agriculture + tourism" (Ammirato et al., 2022). For instance, it uses smart agriculture platforms to achieve visual management of farmland, transforming traditional planting scenarios into sightseeing and experience spots. At the same time, through digital channels such as e-commerce live streaming and online booking, the industrial chain of "agricultural product sales - rural tourism - cultural and creative services" is extended to promote the transformation of the industrial structure from a single production to a composite structure of "production + service + consumption"(Philip and Williams, 2019). In addition, the digital economy promotes the efficient flow of capital, technology, talent and other elements between agriculture and tourism. By integrating cultural and tourism information, agricultural resources and market demand through digital public service platforms, it guides traditional agriculture to upgrade to leisure agriculture and sightseeing agriculture, and promotes the expansion of tourism into areas such as rural ecology and agricultural experience, forming a new structure of coordinated industrial development (Mwesiumo et al., 2022). Ultimately, the integration of agriculture and tourism should evolve from a simple superposition of low added value to a deep integration of high added value.

> Hypothesis 2: The digital economy promotes high-quality development of the integration of agriculture and tourism by optimizing the industrial structure.

2.2.2 The digital economy promotes high-quality development of the integration of agriculture and tourism by improving public services

The digital economy enhances the quality of integration between agriculture and tourism by improving the level of public services. This

is mainly achieved through the use of digital means to establish an inclusive, efficient and collaborative public support system, providing fundamental guarantees and environmental optimization for the integration of agriculture and tourism (Lapuz, 2023). Specifically, the digital economy prompts government departments to establish a comprehensive smart tourism public service platform, integrating regional agricultural resources, cultural heritage, tourism routes, etc., to provide tourists with a full-chain information service covering "dining, accommodation, transportation, sightseeing, shopping and entertainment." This breaks the information barrier that previously made it difficult for tourists to fully understand the details of rural agricultural resources and tourism services, reducing the information asymmetry between supply and demand sides. At the same time, it also opens up public data such as customer source analysis and market trends to enterprises related to agriculture and tourism, reducing the cost of information acquisition and enabling enterprises to more accurately grasp tourists' needs, while tourists can also obtain transparent service information through the platform, further narrowing the information gap. Moreover, the digital economy promotes the standardization of public services and cross-regional collaboration (Quaglione et al., 2020). For example, through the e-government platform, the approval of agricultural and tourism projects can be conducted online. With the help of blockchain technology, a public system for tracking the origin of agricultural products can be established to enhance tourists' trust in consumption. At the same time, it promotes the extension of public services such as medical insurance and transportation to rural tourism scenarios, solving the problem of insufficient "last mile" services. Ultimately, through the digital upgrade of public services, it will eliminate the infrastructure barriers for the integration of agriculture and tourism, lower the operational threshold, and optimize the consumption experience, achieving a quality improvement from "single-point integration" to "system integration."

> Hypothesis 3: The digital economy promotes the high-quality development of the integration of agriculture and tourism by improving public services.

2.2.3 The digital economy promotes high-quality development of the integration of agriculture and tourism by reducing operating costs

Through data-driven and digital tools, it comprehensively reduces the operating costs in the process of the integrated development of agriculture and tourism. Specifically, the digital economy can be applied to links such as agricultural product picking and inventory management, to automate repetitive tasks and reduce direct input such as human resources (Philip and Williams, 2019). As an important carrier of the digital economy, e-commerce platforms connect upstream and downstream enterprises and reduce market circulation costs through mobile payment methods, accelerate the efficient flow of production factors, promote information symmetry between farmers and tourists, and significantly lower marketing and logistics costs. Meanwhile, the digital economy drives the internal process reengineering of traditional industries, enhancing the operational efficiency of the industry through data collaboration (Lopes et al., 2018). Its deep integration with inclusive finance can increase the rate of information transmission, effectively alleviate the information asymmetry between the supply and demand sides of funds, and reduce financing costs. Meanwhile, innovation and entrepreneurship activities in the field of agriculture and tourism integration, relying on the Internet and mobile platforms, can obtain efficient support through the wide coverage of digital economy services and alleviate the constraints of capital costs. The e-commerce transaction model breaks through the limitations of time and space, enabling products to reach users in a timely manner (Ammirato et al., 2022). It not only expands the transaction scope but also reduces transaction costs, ultimately empowering the high-quality development of the integration of agriculture and tourism through multi-dimensional cost optimization.

> Hypothesis 4: The digital economy promotes high-quality development of the integration of agriculture and tourism by reducing operating costs.

2.3 The threshold effect of digital economy promoting the high-quality development of the integration of agriculture and tourism

From the perspective of dynamic change trends, the development of the digital economy has mainly gone through three stages: slow development in the early stage, accelerated development in the middle stage, and super-fast development in the later stage. The impact on the high-quality development of the integration of agriculture and tourism shows nonlinear characteristics. In the early stage of development, the scale of the digital economy held by government departments was relatively small, which led to the fact that the cross-departmental and cross-level sharing advantages of the digital economy had not yet emerged, making it difficult to provide digital resource support for the in-depth integration and development of agriculture and tourism (Li and Yue, 2025). Therefore, at this stage, the enabling effect of the digital economy on the high-quality development of the integration of agriculture and tourism shows certain lagging characteristics. As the digital economy enters a stage of accelerated innovative development, the functions of digital new infrastructure and information network platforms are constantly improving, driving more enterprises to actively participate in the research and development process of agriculture and tourism integration products by relying on big data, 5G and other digital economy technologies, fully releasing the digital dividends of agriculture and tourism integration, and injecting new impetus into the high-quality development of agriculture and tourism integration. During the stage of rapid development of the digital economy, although a higher-level model of agriculture and tourism integration has initially taken shape, the real experience of agricultural work and rural sightseeing in agricultural and tourism scenarios cannot be completely replaced by online platforms (Jiang and Murmann, 2022). This has led to the fact that the business model of the agricultural and tourism industry has not yet achieved further iterative innovation, resulting in the gradual weakening of the promoting effect of the digital economy on the high-quality development of agriculture and tourism integration.

> Hypothesis 5: The role of the digital economy in promoting the high-quality development of the integration of agriculture and tourism has a threshold effect.

3 Methods and materials

3.1 Model setting

3.1.1 Fixed-effect model

The fixed-effect model can control individual non-observed factors that do not change over time, and thus can effectively solve the bias problem caused by the presence of omitted variables in the model. Based on this, a fixed-effect panel model is adopted to test the linear relationship between the level of the digital economy and the quality of high-quality development of agriculture and tourism integration. The Equation (1) is set as follows:

$$ATI_{it} = \alpha_0 + \beta_1 DIG_{it} + \sum_{i=1}^{n} \lambda_k COL_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (1)$$

In the above formula, ATI_{it} and DIG_{it} represent the explained variable and the core explanatory variable, respectively. The subscripts i and t, respectively, represent the province and the year, while COL_{it} and k are a set of control variables. And, respectively, represent the fixed effects of provinces and time, representing the random error term, which follows a normal distribution.

3.1.2 Mediating effect model

From the above analysis, it can be known that the digital economy can promote the high-quality development of the integration of agriculture and tourism by driving the industrial structure, reducing operating costs and improving public services. To test whether the mechanism of public services exists, the following Equations 2 and 3 are constructed to test the mediation effect:

$$Med_{it} = \alpha_0 + \varphi_1 DIG_{it} + \sum_{i=1}^{n} \lambda_k COL_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (2)$$

$$ATI_{it} = \alpha_0 + \omega_1 DIG_{it} + \omega_2 Med_{it} + \sum_{i=1}^{n} \lambda_k COL_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (3)$$

Among them, Med_{it} is the mediating variable, and the meanings of other variables are the same as those in Model (1).

3.1.3 Panel threshold model

The aforementioned theoretical analysis points out that the impact of the digital economy on the high-quality development of the integration of agriculture and tourism shows nonlinear characteristics and may have a threshold effect. This paper takes the digital economy as a threshold variable and constructs a threshold panel model as the following Equation (4):

$$\begin{aligned} ATI_{it} = {} & \alpha_0 + \beta_{11} DIG_{it} \times I(DIG_{it} \le \theta_1) + \beta_{12} DIG_{it} \times I \\ & (\theta_1 \le DIG_{it} \le \theta_2) + \cdots + \beta_{1,n} DIG_{it} \times I(\theta_{n-1} \le DIG_{it} \le \theta_n) \\ & + \beta_{1,n+1} DIG_{it} \times I(DIG_{it} > \theta_1) + \sum_{k=1}^{n} \lambda_k COL_{it,k} + \mu_i + \upsilon_t + \xi_{it} \end{aligned} \quad (4)$$

Among them, θ_1, θ_2, …, and θ_n is the threshold value, and there exist n + 1 threshold intervals,β_{11}, β_{12}, ⋯, $\beta_{1,n}$ is the regression coefficient under different threshold intervals. I(·) is the indicator function. t-1 indicates a lag of one period, and other indicators are defined by referring to Model (1).

3.2 Variable selection

3.2.1 The explained variable

In this study, the high-quality development of agriculture and tourism integration (ATI) is taken as the explained variable. High-quality development is development that can meet the people's ever-growing needs for a better life and is a concentrated embodiment of the new development philosophy. The integration of agriculture and tourism is a new industrial model formed by the intersection of industries. It is a coordinated development based on the deep integration of agriculture and tourism under the background of high-quality development (Liu et al., 2024). The high-quality development of the integration of agriculture and tourism can not only further extend the agricultural industrial chain, optimize the industrial structure, promote the transformation of agriculture towards a multi-functional direction, but also add new vitality to the rural economy. Moreover, it can promote the integration and penetration of agriculture and tourism, infuse cultural connotations and new vitality into the development of the tourism industry, innovate new forms of "agriculture + tourism," and bring comprehensive value to regional development. Referring to the research results of Zhang (2025) and Jiang et al. (2025), the following evaluation index system is constructed to measure the high-quality development level of the integration of agriculture and tourism (Table 1).

This paper adopts the entropy weight TOPSIS method to measure the high-quality development level of the integration of agriculture and tourism. Entropy weight method is a commonly used objective assignment method. To a certain extent, it can avoid the influence of subjective factors and is more suitable for determining the weights of multi-dimensional indicators (Zhang et al., 2011). The TOPSIS model is a method for approximating the ideal ranking in multi-objective decision analysis (Chen et al., 2023). By calculating the distance between the evaluated object and the ideal solution, the evaluation score of the object is obtained. Therefore, on the basis of determining the weights by the entropy method, combined with the TOPSIS model, the distance between the object and the positive and negative ideal values can be effectively measured for evaluation and ranking of superiority and inferiority.

3.2.2 The explanatory variable and the threshold variable

The core explanatory variable of this article is the level of digital economic development (DIG). The digital economy is the main economic form following the agricultural economy and the industrial economy. It is a new economic form that takes data resources as the key element, modern information networks as the main carrier, and the integrated application of information and communication technologies and the digital transformation of all factors as important driving forces, promoting a more unified fairness and efficiency. Referring to the digital economy indicator system proposed by Ye (2025), this indicator system is comprehensively established based on the connotation of the digital economy, focusing on the conditions, applications and environment of the digital economy. It consists of 4 target layers, 9 sub-indicators and 30 variables. For details, please refer to Table 2. This paper adopts the entropy weight TOPSIS method to measure the development level of the digital economy.

TABLE 1 Evaluation system for the high-quality development level of agriculture and tourism integration.

System layer	Dimension	Criterion layer	Indicator layer	Attributes
High-quality development of agriculture and tourism integration	Innovation	Innovation ability	Agricultural technology level[a] (ten thousand kilowatts)	+
			Financial input for tourism science and technology (person/year)	+
			Agricultural fiscal input level (in billions of yuan)	+
			The number of tourism patent authorizations	
	Coordination	Innovation Industrial	Proportion of the primary industry (%)	+
			Grain output (ten thousand kilograms)	+
			Proportion of total tourism revenue in the tertiary industry (%)	+
			Land element allocation (thousand hectares)	+
			Degree of coupling of agriculture and tourism integration (%)	+
			Coordination degree of integration between agriculture and tourism (%)	+
	Green	Green development	Effective irrigated area (thousand hectares)	+
			Fertilizer application rate (ten thousand kilograms)	−
			Green coverage rate (%)	+
			Park green space area (ten thousand hectares)	+
			Garbage collection volume (ten thousand kilograms)	+
			Garbage disposal rate (%)	+
	Open	External communication	Number of inbound tourists (person-times)	+
			Number of star-rated hotels (in)	+
			Number of art performance group institutions (units)	+
	Share	Sharing of people's livelihood	Agricultural economic benefits (in billions of yuan)	+
			Number of public library industry institutions (units)	+
			Number of museums	+
			The ratio of total tourism revenue to total population (%)	+
			The ratio of agricultural and tourism revenue to GDP (%)	+

[a]The total power of agricultural machinery is used to represent the level of agricultural technology.

10.3389/fsufs.2025.1751812

3.2.3 The mediating variable

Based on the aforementioned theoretical analysis, this paper selects industrial structure (Str), operating cost (Psl), and public service (Ncp) as mediating variables. The industrial structure is measured by the indicator of industrial rationalization. Industrial rationalization (ISR) refers to the rational allocation of factors among various industries, and is generally measured by the Theil Index (Guo et al., 2022; Wei et al., 2023). Drawing on the practice of Yin and Yu (2022), the operating costs are measured by taking the logarithm of the digital inclusive finance index. Drawing on the practice of Huang J. et al. (2025) and Huang M. et al. (2025), an evaluation system for the level of basic public services in rural areas is constructed from four dimensions: infrastructure, medical care and social security, culture, science and education, and environmental governance. The entropy weight TOPSIS model method is also used to measure its development level.

3.2.4 The control variables

Considering that the high-quality development of the integration of agriculture and tourism is a complex process that may be influenced

TABLE 2 Evaluation index system for the development level of the digital economy.

Dimension	Criterion layer	Indicator layer	Attributes
Carriers of digital economic development	Traditional infrastructure	The number of Internet broadband access ports (Ten thousand)	+
		The number of Internet broadband access users (Ten thousand)	+
		The number of domain names per thousand people (Ten thousand)	+
		The number of websites per thousand people (Ten thousand)	+
	New digital infrastructure	Fixed investment in the electronic information industry (One billion yuan)	+
		The number of mobile phone base stations (Ten thousand)	+
		Number of IPV4/IPV6 addresses (Ten thousand)	+
Digital industrialization	Industrial scale	Total volume of telecommunications services (One billion yuan)	+
		Revenue scale of software products (One billion yuan)	+
		The scale of information service revenue (One billion yuan)	+
	Types of industries	The number of ICT listed companies (Number)	+
		The number of top 100 Internet enterprises (Number)	+
		The number of manufacturing enterprises in the electronic information industry (Number)	+
Industrial digitalization	Digitalization of agriculture	The proportion of administrative villages that have launched Internet broadband services (%)	+
		Rural broadband access users (Ten thousand)	+
		The e-commerce volume of agricultural products (One billion yuan)	+
	Digitalization of Industrial enterprises	The proportion of industrial application Internet (%)	+
		The number of computers used per 100 people in industrial enterprises (Number of units)	+
		Integration index of informatization and industrialization	+
		E-commerce transaction volume of industrial enterprises (One billion yuan)	+
	Digitalization of services	The proportion of enterprises engaged in e-commerce transaction activities	+
		E-commerce transaction volume (One billion yuan)	+
		Investment in Internet-related service industries (One billion yuan)	+
		Digital HP Financial Index	+
The development environment of the digital economy	Governance of the environment	The number of Weibo accounts of government agencies (Number)	+
		Government affairs application index	+
		The number of digital intellectual property transaction contracts (Number)	+
	Innovative environment	R&D expenditure (One billion yuan)	+
		The employment ratio of digital knowledge talents (%)	+
		The number of software development personnel employed (Person)	+

by various external factors, the degree of government support (Gov), the level of financial development (Fin), the degree of transportation convenience (Tci), the level of economic development (Gdp), and the degree of marketization (Dom) are selected as control variables. Among them, the degree of government intervention is characterized by the proportion of local government general public budget expenditure to GDP (Shen et al., 2025), the level of financial development is measured by the ratio of the sum of the deposit balance and loan balance of financial institutions to GDP (Wang and Mei, 2024), the level of transportation infrastructure is represented by the logarithm of road mileage, and the level of economic development is represented by the logarithm of the per capita GDP of the province. The degree of marketization is expressed by the marketization index by province.

3.3 Data sources and sample characteristics

This paper conducts an empirical analysis using data from 30 provinces in China from 2012 to 2023. Based on the availability of data, Hong Kong, Macao, Taiwan and Xizang have not been included as research samples for the time being. The data mainly come from the "China Rural Statistical Yearbook," "China Statistical Yearbook," "China Agricultural Yearbook," "China Culture and Tourism Statistical Yearbook," "China Population and Employment Statistical Yearbook," "China Agricultural Products Trade Report," "China Environmental Statistical Yearbook," "China Social Statistical Yearbook," etc. In addition, there are the statistical yearbooks of the National Bureau of Statistics, the Ministry of Culture and Tourism, the Ministry of Agriculture and Rural Affairs, and the statistical bulletins of national economic and social development of each province. The industrial structure data mainly comes from the OECD Patent Statistical Bulletin. All data measured in monetary units were deflated with 2012 as the base period, and quantitative analysis and model estimation were conducted using R software. The descriptive statistical results of the variables are shown in Table 3.

4 Results and analysis

4.1 Multicollinearity test

Generally speaking, the higher the VIF value, the more severe the collinearity between the explanatory variable and the dependent variable (Roberts and Townsend, 2016). According to the multicollinearity judgment criterion, when $0 < VIF \leq 10$, there is no multicollinearity among the variables. When $10 < VIF < 100$, there is a strong collinearity among the variables. If VIF is ≥ 100, there is severe multicollinearity. Table 4 shows the multicollinearity test results of the model. It can be seen that the VIF values of each variable are all less than 10, so the indicators selected in this paper do not have collinearity.

4.2 Benchmark regression results

The regression results of the impact of the digital economy on the high-quality development of agriculture and tourism integration based on the fixed-effect model is shown in Table 5. Column (1) presents the regression results without control variables. Column (2)

TABLE 3 Descriptive statistical results of variables.

Variable type	Variable	Variable symbol	Mean	Standard deviation	Minimum value	Maximum value
The explained variable	High-quality development level of agriculture and tourism integration	ATI	0.143	0.161	0.040	0.859
Core explanatory variable	The development level of digital economy	DIG	0.121	0.165	0.018	0.776
Mediating variable	Industrial structure	Str	19.832	11.321	2.008	71.843
	Operating costs	Psl	4.225	0.443	2.541	6.887
	Public service	Ncp	0.416	0.079	0.219	0.766
Control variable	The degree of government support	Gov	0.203	0.067	0.112	0.656
	The level of financial development	Fin	4.543	0.932	3.579	7.321
	The development level of transportation	Tci	9.652	0.737	8.720	12.134
	Economic development level	Gdp	1.092	0.505	−0.143	2.316
	Degree of marketization	Dom	7.026	1.171	6.432	11.401

TABLE 4 Results of multicollinearity test.

Variable	VIF	1/VIF
ATI	7.65	0.1307
DIG	2.63	0.2306
Str	4.10	0.3279
Psl	2.73	0.3663
Ncp	3.19	0.3135
Gov	1.88	0.5319
Fin	4.22	0.2370
Tci	1.79	0.5587
Gdp	2.28	0.4386

TABLE 5 Benchmark regression results.

Variables	(1)	(2)	(3)
DIG	0.432*** (3.012)	0.401*** (3.256)	0.379*** (4.021)
Gov		0.236***(3.365)	0.218*** (3.962)
Fin		0.231*** (3.426)	0.224*** (3.845)
Tci		0.227*** (3.151)	0.203*** (3.625)
Gdp			0.098** (2.032)
Dom			0.125** (2.137)
Time-fixed effect	Yes	Yes	Yes
Individual-fixed effect	Yes	Yes	Yes
Constant term	1.276** (2.612)	1.032** (2.524)	1.013** (2.631)
R^2	0.715	0.722	0.795
Sample size	360	360	360

***, **, and * Indicate significance at the 1, 5, and 10% levels, respectively.

shows the regression results after introducing the degree of government support, the level of financial development, and the convenience of transportation. Column (3) presents the regression results after further introducing the level of economic development and the degree of marketization. Analysis shows that regardless of whether control variables are added or not, the coefficient of the digital economy is significantly positive at the 1% level. Moreover, the results in column (3) have slightly decreased compared with those in columns (1) and (2), but the significance has not changed significantly. This indicates that regardless of whether influencing factors are controlled or not, the digital economy can promote the high-quality development of the integration of agriculture and tourism. Therefore, hypothesis 1 has been verified.

4.3 Endogeneity treatment and robustness test

4.3.1 Endogenous treatment

Using only regression models to determine causal relationships may overlook reverse causality and the endogeneity problem caused by missing variables. In view of this, this paper adopts the instrumental variable method to conduct a two-stage least squares (2SLS) regression to address the endogeneity problem. Firstly, referring to the research of Lin et al. (2025) the interaction term (IV1) between the per capita postal and telecommunications business volume in 1995 and the time trend term was selected as the instrumental variable of the digital economy. The results are shown in columns (1) and (2) of Table 6. Secondly, the lagging term (IV2) of the core explanatory variable digital economy was selected as the instrumental variable, and the results are shown in columns (3) and (4) of Table 6. It can be seen that the unidentifiable test rejects the null hypothesis that the instrumental variable is unidentifiable. The *p*-value of the weak instrumental variable test is less than 0.1, and all the statistics are greater than the critical value at the 10% level, indicating that the selection of instrumental variables is effective. The coefficients of the digital economy are all significantly positive at the 1% level, consistent with the benchmark regression results, confirming the robustness of the conclusion.

4.3.2 Robustness test

Here, the robustness test is conducted through the following methods:

(1) Replacing the explained variable. Referring to the research of Ma Y. et al. (2025); Ma Z. et al. (2025), the number of news releases related to the integration of agriculture and tourism in each province was used as a proxy variable for the high-quality

TABLE 6 Endogeneity test results.

Variables	(1)	(2)	(3)	(4)
	The first stage	The second stage	The third stage	The Fourth stage
	DIG	ATI	DIG	ATI
DIG		0.534*** (3.685)		0.602*** (4.215)
IV_1	0.156*** (3.256)			
IV_2			0.210*** (3.026)	
Control variable	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes
Individual-fixed effect	Yes	Yes	Yes	Yes
K-P rk LM	45.321 [0.001]		55.845 [0.000]	
K-P rk Wald F	63.213 {16.380}		72.365 {16.380}	
Constant term	0.563** (2.007)	0.865** (2.324)	0.675** (2.034)	0.963** (2.135)
R^2	0.765	0.747	0.769	0.754
Sample size	360	360	330	330

{} represents the critical value of the Stock-Yogo test at the 10% level, and [] indicates the p value.

TABLE 7 Results of robustness tests.

Variables	(1)	(2)	(3)
DIG	0.421*** (3.412)	0.388*** (3.548)	0.434*** (3.825)
Control variable	Yes	Yes	Yes
Time fixation effect	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes
Constant term	0.741** (2.113)	0.825** (2.226)	0.615** (2.134)
R^2	0.737	0.707	0.779
Sample size	360	312	312

*** and ** indicate significance at the 1 and 5% levels, respectively.

development of the integration of agriculture and tourism for regression again. The results are shown in column 8 (1) of Table.

(2) Excluding samples from municipalities directly under the Central Government. Municipalities directly under the Central Government have certain advantages in urban construction, talent attraction and other aspects, which may cause interference to the regression results. Therefore, after excluding the data of Beijing, Chongqing, Tianjin and Shanghai and regressing again, the results are shown in column (2) of Table 7.

(3) The tail reduction treatment. To avoid interference from outliers, the sample data were truncated by 1 and 99%, respectively, and then regressed again. The results are shown in column 8 (3) of Table. It can be seen that after a series of robustness tests, the coefficient of the digital economy remains significantly positive at the 1% level, indicating that the benchmark conclusion that the digital economy can empower the high-quality development of the integration of agriculture and tourism is robust.

4.4 Mediating effect test

The aforementioned discussion analyzed the impact mechanism of the digital economy on ATI from three perspectives: promoting industrial structure, reducing operating costs, and improving public services. Hypothesis testing was conducted using panel data, and the results are shown in Table 8.

4.4.1 The industrial structure optimization effect of the digital economy

The second column of Table 8 shows that the regression coefficient of the digital economy on the industrial structure is 0.147 ($p < 5\%$). The results in the third column show that after adding the industrial structure variable to the benchmark model, the coefficients of the two core independent variables are significantly positive, indicating that the industrial structure variable plays a partial mediating role in the process of digital economy empowering the high-quality development of the integration of agriculture and tourism. Research Hypothesis 2 has been verified. After calculation, the proportion of the mediating effect is 17.043%. The main reasons are as follows: On the one hand, the digital economy provides data empowerment and technical support for agricultural production and tourism services. For instance, it optimizes the allocation of agricultural resources through big data analysis and realizes the traceability and intelligent management of agricultural products through Internet of Things technology, promoting the improvement of agricultural production efficiency and the upgrading of the quality of characteristic agricultural products, laying a high-quality

TABLE 8 Regression results of mediating effect.

Industrial structure optimization effect			Public service promotion effect			Operational cost saving effect		
Variable	*Str*	*ATI*	Variable	*Psl*	ATI	Variable	*Ncp*	*ATI*
DIG	0.149** (2.216)	0.425*** (2.738)	*DIG*	0.182*** (2.053)	0.427*** (2.943)	*DIG*	−0.214** (−2.318)	0.433*** (3.105)
Str	—	0.586*** (5.473)	*Psl*	—	0.404*** (4.321)	*Ncp*	—	−0.327*** (−5.276)
Mediating effect ratio	—	17.043%	Mediating effect ratio	—	14.676%	Mediating effect ratio	—	13.540%

*, **, and *** denote significance at 10%, 5, and 1% level, respectively.

resource foundation for the integration of agriculture and tourism. On the other hand, the industrial structure has accelerated the digital transformation of tourism services (Li et al., 2024; Liu et al., 2024). Applications such as VR experiences, online booking platforms, and intelligent navigation systems have enhanced tourists' immersive experiences and convenience. At the same time, digital marketing has expanded the market reach of agricultural and tourism products, promoting in-depth collaboration between agriculture and the tourism industry. Ultimately, achieve the high-quality development goal of enhancing the efficiency of resource integration, optimizing service quality, and extending the value of the industrial chain.

4.4.2 The public services improvement effect of the digital economy

Column 5 of Table 8 shows that the regression coefficient of the digital economy on public services is 0.182 ($p < 1\%$). The results in column 6 show that after adding the public service variable to the benchmark model, the coefficients of the two core independent variables are significantly positive, indicating that the public service variable plays a partial mediating role in the process of digital economy empowering the high-quality development of the integration of agriculture and tourism. This conclusion is consistent with the research findings of Wang et al. (2023). And Hypothesis 3 has been verified. After calculation, the proportion of the mediating effect is 14.676%. The main reason is that during the development of the digital economy, it has promoted the transformation of regional public services towards digitalization and platformization. By building a digital information database covering agricultural resources, cultural elements and tourism services, the information barriers between urban and rural areas are broken down and the consumption demands of cities are precisely matched. Based on the independently collected consumption feedback data, the supply structure is optimized in reverse to promote the transformation of agricultural production towards "tourism-oriented," the transformation of cultural resources into experiential scenarios, and the upgrading of tourism services to integrated products, achieving a dynamic balance between demand and supply. By formulating service standards and norms and establishing a collaborative platform involving multiple entities such as the government, agricultural cooperatives, cultural and tourism enterprises, and villagers' organizations, the intensive utilization of resources and the coordination of interests can be promoted. Ultimately, relying on digital infrastructure, service efficiency and consumption experience can be enhanced,. Promote the transformation of the integration of agriculture, culture and tourism from the traditional resource-driven model to a high-quality development model oriented towards consumer demand and centered on cultural value.

4.4.3 The operation cost saving effect of the digital economy

Column 7 of Table 8 shows that the regression coefficient of the digital economy on operating costs is −0.214 ($p < 5\%$). The results in column 8 show that after adding the variable of operational cost income to the benchmark model, the coefficients of the two core independent variables are significantly negative, indicating that the variable of operational cost income plays a partial mediating role in the high-quality development of the integration of agriculture and tourism driven by the digital economy. Research Hypothesis 4 has been verified. After calculation, the proportion of the mediating effect is 13.540%. The main reasons are as follows: On the one hand, digital technology helps to enhance the operational efficiency of the agricultural and tourism industry. For instance, it optimizes the procurement and logistics costs of agricultural products through digital supply chain management, and reduces the operating expenses of scenic spots through intelligent energy consumption monitoring. Meanwhile, big data demand forecasting reduces inventory overstock and resource waste, directly promoting the optimization of the operational cost structure and the improvement of the input–output ratio. On the other hand, the digital economy can expand the sources of income for agricultural and tourism operations. For instance, online booking platforms can increase the booking rate of guest rooms and experience projects, and live-streaming sales and e-commerce channels can enhance the sales of added value of agricultural products, significantly raising the average transaction value and repurchase rate, thus forming a virtuous cycle of operation driven by both cost reduction and revenue increase. Provide sustainable financial support for the facility upgrade, service innovation and scale expansion of agriculture and tourism integration projects, thereby promoting high-quality development.

4.5 Heterogeneity analysis

4.5.1 Heterogeneity of agricultural resource basis

Agricultural resources and characteristics are an important foundation for the integrated development of agriculture and tourism. National-level geographical indication agricultural products are scarce resources formed by relying on specific natural environments and traditional techniques. In the integration of agriculture and tourism,

such products are the core "agricultural IP" that attract tourists. The quantity directly reflects the regional characteristic concentration and industrial advantages of agricultural resources in a region. Therefore, this paper uses the quantity of national geographical indication agricultural product brands to represent the regional agricultural resource foundation. For this purpose, the median was used as the criterion for classifying regions with high and low agricultural resource bases, and the research samples were divided into two groups for regression (as shown in Table 9). As can be seen from columns (1) and (2) of Table 9, the impact coefficient of the digital economy on the high-quality development of agriculture and tourism integration in regions with different agricultural resource bases is significantly positive at the 1% level. However, the impact coefficient in regions with high agricultural resource bases is much greater than that in regions with low rural cultural resource endowments. This indicates that the digital economy plays a more significant role in enabling the high-quality development of the integration of agriculture and tourism in regions with a high agricultural resource base. The reason for this is that regions with a high agricultural resource base have more abundant agricultural production scenarios and characteristic resources, providing a broad application space for the digital economy. The digital economy can enhance production efficiency through smart agricultural management, strengthen brand trust by relying on the traceability system for agricultural products, and connect the "production - sales - cultural tourism" chain by leveraging e-commerce live streaming and VR agricultural experiences. Meanwhile, the combination of large-scale agricultural landscapes and the digital economy can develop immersive agricultural tourism products. Additionally, with the policy's support and inclination towards the digitalization of advantageous agriculture, it can quickly achieve the transformation of resource value and the extension of the industrial chain, so its enabling effect is more significant.

4.5.2 Heterogeneity of rural cultural resource endowment

Regional cultural resources, with the characteristic of rural cultural resources, are the key support for the upgrade of the integration of agriculture and tourism from "resource superposition" to "value symbiosis." Intangible cultural heritage and traditional skills are the core carriers of rural culture, providing "consumable cultural content," and their quantity directly reflects the diversity and uniqueness of regional cultural resources. Ancient villages are the material carriers of rural culture and can provide "experiential cultural Spaces." Their quantity reflects the preservation quality and scarcity of regional cultural resources. Therefore, both are important resources and carrier foundations for the integration of agriculture and tourism. For this purpose, this paper uses the number of intangible cultural heritage and traditional skills and the number of ancient villages at or above the provincial level to represent the cultural resource endowment of rural areas in a region, and takes the median as the classification criterion for regions with high or low cultural resource endowment. The research samples are divided into two groups for regression (as shown in Table 9). As can be seen from columns (3) and (4) of Table 9, the impact coefficient of the digital economy on the high-quality development of agriculture and tourism integration in regions with different rural cultural resource endowments is significantly positive at the 1% level. However, the impact coefficient in regions with high rural cultural resource endowments is much greater than that in regions with low rural cultural resource endowments. This indicates that the digital economy has a more significant enabling effect on the high-quality development of the integration of agriculture and tourism in rural areas with high cultural resource endowments. The reason for this is that regions with high rural cultural resource endowments provide more diverse application scenarios and transformation carriers for the digital economy. A large number of diverse cultural resources can be dynamically inherited, experienced in an immersive way and commercially transformed through the digital economy. Moreover, the cluster effect of resources further amplifies the integration value of the digital economy. Meanwhile, such regions are often accompanied by policy preferences and high market demand, driving the digital economy to upgrade from shallow applications to deep empowerment (Pang et al., 2022). Therefore, the enabling effect is more significant.

4.6 Threshold effect test

To demonstrate whether the impact of the digital economy on the high-quality development of the integration of agriculture and tourism has nonlinear characteristics, a threshold effect regression model is now used for testing. The first step in testing the threshold effect regression model is to determine the threshold value and the number of threshold

TABLE 9 Results of heterogeneity analysis.

Variables	(1)	(2)	(3)	(4)
	Regions with high agricultural resources	Regions with low agricultural resources	Regions with high tourism resource endowments	Regions with low tourism resource endowments
DIG	0.621*** (4.321)	0.311*** (3.013)	0.762*** (4.563)	0.402*** (3.216)
Control variables	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes
Individual-fixed effect	Yes	Yes	Yes	Yes
Constant term	2.165** (2.234)	1.523** (2.061)	1.675** (2.234)	0.773** (2.165)
R^2	0.699	0.701	0.775	0.724
Sample size	180	180	180	180

*, **, *** denote significance at 10%, 5, and 1% level, respectively.

TABLE 10 Results of threshold characteristic test.

Threshold variable	Model tests	Estimate of the threshold value	F-statistic	*P* value	Critical values		
					1%	5%	10%
DIG	Single threshold	0.412	21.548***	0.003	14.097	6.865	4.432
	Double threshold2	Threshold 1:0.412 Threshold 2:0.638	14.237**	0.028	21.943	14.843	10.132
	Three thresholds	–	2.221	0.170	5.909	2.558	1.029

*** and ** indicate significance at the 1 and 5% levels, respectively. The values in parentheses are the T-values.

TABLE 11 Estimation results of threshold effect.

Variables	ATI
DIG×I(DIG≤0.412)	0.282 (1.203)
DIG×I(0.412 < DIG≤0.638)	0.673*** (5.139)
DIG×I(DIG>0.638)	0.435** (2.811)
Control variables	YES
Time-fixed effect	YES
Individual-fixed effect	YES
Constant term	1.065** (2.145)
R^2	0.776
Sample size	360

*** and ** indicate significance at the 1 and 5% levels, respectively. The values in parentheses are the T-values.

value variables (Yuan et al., 2023). For this purpose, DIG was used as the threshold variable. In both the single-threshold and double-threshold tests, the F-statistic passed the significance level test (as shown in Table 10), and all the null hypotheses were rejected. However, in the triple-threshold effect test, the F-statistic failed the significance level test, and the null hypotheses could not be rejected. From this, it can be known that there exists a "double threshold" effect.

The regression results of the threshold model is shown in Table 11. It can be seen that when the level of the digital economy is less than or equal to the threshold value of 0.412, the coefficient of the digital economy has not passed the significance test, indicating that the digital economy in its early stage of development has no significant impact on the high-quality development of the integration of agriculture and tourism. When the level of the digital economy is between 0.412 and 0.638, the coefficient of the digital economy is 0.673, and it passes the significance test at the 1% level, indicating that when the digital economy is in the middle stage of development, its enabling effect on the high-quality development of the integration of agriculture and tourism is strong. When the level of the digital economy crossed the threshold value of 0.638, the coefficient of the digital economy was 0.435, and it passed the significance test at the 5% level, indicating that the promoting effect of the digital economy on the high-quality development of the integration of agriculture and tourism is gradually weakening. In conclusion, the driving effect of the digital economy on the high-quality development of the integration of agriculture and tourism shows a non-linear characteristic of being not significant in the initial stage, strengthening in the middle stage, and weakening in the later stage. Thus, Hypothesis 5 is verified. One possible reason is that in the early stage, the rural digital infrastructure is weak with insufficient networks and smart terminals. The application of technology merely remains at the surface level, such as being used merely for simple publicity. At the same time, the collaboration between agriculture and tourism industries is lacking (Jiang and Murmann, 2022), and there is a shortage of comprehensive talents and resources. Consumers' acceptance of digital agricultural tourism products is low. This has led to the difficulty in demonstrating the application effects of the digital economy in the promotion of characteristic agricultural products and rural sightseeing projects. After entering the middle stage, with the improvement of digital rural policies and the decline in the cost of technology application, the smart agriculture monitoring system has achieved dynamic prediction of farmland yields. Rural tourism has precisely pushed content such as picking experiences and folk activities through short video platforms, effectively stimulating interest in experiences and consumption willingness, and accelerating the release of agricultural and tourism consumption demands. In the later stage of development, when the digital economy has widely covered the agricultural and tourism scenarios, the problem of homogenization has gradually emerged: in most regions, agricultural product e-commerce platforms present a single model of "live-streaming sales + standardized packaging," the online marketing of rural homestays is highly homogenized, and the digital interactive design of agricultural experience projects lacks novelty, leading to a weakening of the marginal boosting effect of the digital economy on consumption appeal (Zhang et al., 2025).

5 Conclusions and policy recommendations

5.1 Conclusion

Based on the panel data of 30 provinces in China from 2012 to 2023, the empirical study using fixed effect, mediating effect and threshold effect models shows the following: First, the digital economy has a significant promoting effect on the high-quality development of agricultural tourism integration, which effectively expands the research content of the enabling effect of digital economy; Second, the driving effect of the digital economy is stronger in regions with abundant agricultural/cultural resources endowments, this finding breaks the homogeneous perception of the effect of digital economy; Third, the digital economy promotes the high-quality development of agricultural tourism integration through promoting industrial structure upgrading, saving operational costs and improving public services, among which the mediating effect of improving public services has been less discussed in existing studies, thus this research enriches the mechanism system of the effect of digital economy; Fourth, it is found that the effect of the digital economy on the high-quality development of agricultural tourism integration has a dual threshold characteristic, that is, the initial effect is not significant, the effect strengthens in the middle stage, and the marginal

effect decreases in the later stage. This is different from the widely recognized view that "the enabling effect of digital economy continuously increases," therefore this conclusion can provide a new perspective for different regions to adjust strategies at different stages.

5.2 Policy recommendations

Based on the above research conclusions, the following policy recommendations are hereby proposed to fully leverage the role of the digital economy in promoting the high-quality development of the integration of agriculture and tourism.

First, adopt multiple measures to promote the development of the digital economy. Government departments should formulate targeted support policies for the development of the digital economy, increase the proportion of fiscal expenditure on digital technology research and development and digital talent cultivation, and provide support for the construction of rural digital infrastructure, the digital transformation of agricultural production and rural tourism, and the development of agricultural product data resources, so as to lay a solid foundation for promoting the digital economy and facilitate the high-quality development of the integration of agriculture and tourism (Shen and Hu, 2024). Research institutions should carry out core technology research and development around national strategic demands such as quantum computing and artificial intelligence, collaborate with leading digital economy enterprises, establish digital technology research centers, accelerate the research and development of common technologies such as agricultural product traceability systems and smart agricultural management platforms, drive the development of the digital economy, and thereby promote the high-quality development of the integration of agriculture and tourism.

Second, adopt differentiated strategies for the integrated development of agriculture and tourism based on local conditions. Regions with high agricultural resources should focus on geographical indication Ips, extend the industrial chain through smart management, traceability, and e-commerce live streaming, develop agricultural tourism projects, and accelerate monetization and upgrading (Zhao et al., 2022). In areas with low agricultural resources, efforts should be made to enhance the integration of ecology, culture and light experience. Focus on natural ecology or fragments of intangible cultural heritage, attract customers with short videos, develop low-cost experience projects, and collaborate with regions to undertake health care and study Tours. Policy support and lightweight tools should be used to improve efficiency. Regions with high cultural resource endowments can rely on intangible cultural heritage and ancient villages to deepen the dynamic inheritance, immersive experience and commercial transformation of the digital economy, and promote cluster development. Low-cultural resource areas should focus on the positioning of "small but beautiful," explore local symbols to cultivate micro-ips, empower with lightweight digital tools, coordinate regional efforts to attract tourists, develop original ecological experiences, and strive for policy support for infrastructure training.

Third, cultivate the main body to stimulate the vitality of the integrated development of agriculture and tourism. Talents have always been the fundamental force for the integrated development of industries. The application of digital technology in the integration of agriculture and tourism requires a large number of talents to support it. Therefore, efforts should be made to enhance the cultivation of digital economy talents' participation in the agricultural and tourism industry, which to a certain extent can address the shortage of such talents (Shen et al., 2025). All regions should adopt flexible measures for talent introduction and cultivation policies to enhance the digital literacy of talents. On the one hand, high-quality talents in related fields can be introduced through cooperation with major universities, and more college graduates can be attracted to join by holding lectures, or corresponding courses can be offered within the school. On the other hand, differentiated training can be provided for highly educated talents at different job levels. For instance, for grassroots skilled talents, innovative digital skills can be cultivated, such as short video production and live streaming platform operation. In addition, technicians can be sent to farmers' homes to gain a thorough understanding of them and teach them the operation methods step by step, thereby increasing the actual resources obtained by rural and remote areas. During this process, relevant technicians also got the opportunity to participate in actual projects for learning, achieving full practice from planning to implementation. In addition, for practitioners with certain digital technology skills, it is advisable to enhance their training in digital technology, such as the setting of data scenarios for the high-quality development of agriculture and tourism, and market monitoring in related industries (Wang et al., 2022). For professional and technical talents who have already mastered the application of digital technology, they can be guided to carry out new agriculture and tourism integration industrial structure and product research and development.

Data availability statement

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

Author contributions

TL: Validation, Conceptualization, Writing – original draft, Methodology, Data curation. JW: Supervision, Writing – review & editing, Investigation.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This research was financially supported by Project of Hunan Provincial Natural Science Foundation "Research on the Path and Effects of Empowering High-Quality Development of Cultural Tourism Integration by Digital Economy" (20241 J72406) and "Digital Economy and Intelligent Management" Key Laboratory Project of Ordinary Universities in Hunan Province.

Acknowledgments

The authors would like to thank the editors and reviewers for their insightful comments and suggestions.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Ammirato, S., Felicetti, A. M., Linzalone, R., and Carlucci, D. (2022). Digital business models in cultural tourism. *Int. J. Entrep. Behav. Res.* 28, 1940–1961. doi: 10.1108/IJEBR-01-2021-0070

Ayyildiz, A. Y., and Koc, E. (2024). "Promotion of Agritourism as a sustainable form of tourism" in Rethinking sustainable tourism in geographical environments: Theory and practices (Cham: Springer), 209–219.

Bukht, R., and Heeks, R. (2018). Defining, conceptualizing and measuring the digital economy. *Int. Organ. Res. J.* 13, 143–172. doi: 10.17323/1996-7845-2018-02-07

Chang, H. H., Mishra, A. K., and Lee, T. H. (2019). A supply-side analysis of agritourism: evidence from farm-level agriculture census data in Taiwan. *Aust. J. Agric. Resour. Econ.* 63, 521–548. doi: 10.1111/1467-8489.12304

Chen, X., Un, C., Wong, I., Lam, J. F. I., and Zhang, H. (2023). Building a sustainable food security evaluation system for the Yangtze River Economic Belt: analysis based on entropy weight TOPSIS model method. *J. Infrastr. Policy Dev.* 7, 1–18. doi: 10.24294/jipd.v7i3.2547

Collins, L., Hill-Sullins, N., Ellis, D. J., and Cozma, R. (2024). Exploring the determinants of Agritourism business owners' expansion intention. *J. Appl. Commun.* 108:4. doi: 10.4148/1051-0834.2528

Guo, H., Gu, F., Peng, Y., Deng, X., and Guo, L. (2022). Does digital inclusive finance effectively promote agricultural green development?—a case study of China. *Int. J. Environ. Res. Public Health* 19:982. doi: 10.3390/ijerph19126982

Huang, M., Hua, M., Li, J., and Han, Y. (2025). Digital economy empowered entrepreneurship. *Manag. Decis.* 63, 155–186. doi: 10.1108/MD-09-2023-1650

Huang, J., Lu, H., and Du, M. (2025). Can digital economy narrow the regional economic gap? Evidence from China. *J. Asian Econ.* 98:101929. doi: 10.1016/j.asieco.2025.101929

Jiang, H., and Murmann, J. P. (2022). The rise of China's digital economy: an overview. *Manag. Organ. Rev.* 18, 790–802. doi: 10.1017/mor.2022.32

Jiang, J., Liang, Y., and Zhang, C. (2025). The logical mechanism of digital empowerment for the itegrated development of agriculture, culture, and tourism, *Reform*, 141–151.

Kaswanto, A. (2015). Land suitability for Agrotourism through agriculture, tourism, beautification and amenity (ATBA) method. *Proc. Environ. Sci.* 24, 35–38. doi: 10.1016/j.proenv.2015.03.006

Khairabadi, O., Sajadzadeh, H., and Mohammadianmansoor, S. (2020). Assessment and evaluation of tourism activities with emphasis on agritourism: the case of simin region in Hamedan City. *Land Use Policy* 99:105045. doi: 10.1016/j.landusepol.2020.105045

Lapuz, M. C. M. (2023). The role of local community empowerment in the digital transformation of rural tourism development in the Philippines. *Technology in Society*, 74, 102308. doi:10.1016/j.techsoc.2023.102308

Li, H., Xie, S., and Su, M. (2024). Does digital technology innovation promote low-carbon development in agriculture? A spatial econometric analysis based on 31 provinces in China. *Environ. Sci. Pollut. Res.* 31, 4478–4499. doi: 10.1007/s11356-023-31369-9

Li, X., and Yue, S. (2025). Does the government digital attention improve China's digital economy output efficiency: accelerator or inhibitor. *Econ. Anal. Policy* 85, 607–625.

Lin, Q., Jian, Y., Zhang, D., Li, J., and Mao, S. (2025). Exploring the "double-edged sword" effect of the digital economy on sustainable agricultural development: evidence from China. *Sustain. Horiz.* 13:100122. doi: 10.1016/j.horiz.2024.100122

Liu, H., Tan, Z., and Xia, Z. (2024). The coupling coordination relationship and driving factors of the digital economy and high-quality development of rural tourism: insights from Chinese experience data. *Land* 13:734. doi: 10.3390/land13111734

Lopes, A. P. F., Muñoz, M. M., and Alarcón-Urbistondo, P. (2018). Regional tourism competitiveness using the PROMETHEE approach. *Ann. Tour. Res.* 73, 1–13. doi: 10.1016/j.annals.2018.07.003

Lu, S., Zhuang, J., Sun, Z., and Huang, M. (2024). How can rural digitalization improve agricultural green total factor productivity: empirical evidence from counties in China. *Heliyon* 10:e35296. doi: 10.1016/j.heliyon.2024.e35296

Luo, C., and Wu, X. (2022). Research on the integrated development of leisure agriculture and red cultural tourism under the background of big data. *Acta Agric. Scand. Sect. B* 72, 189–199. doi: 10.1080/09064710.2021.2007993

Ma, Y., Wei, R., and Bi, H. (2025). How does digital inclusive finance enhance rural economic resilience? — a study based on provincial panel data in China. *PLoS One* 20:e0321630. doi: 10.1371/journal.pone.0321630

Ma, Z., Xiao, H., Li, J., Chen, H., and Chen, W. (2025). Study on how the digital economy affects urban carbon emissions. *Renew. Sust. Energ. Rev.* 207:114910. doi: 10.1016/j.rser.2024.114910

Ma, Z., and Zhang, P. (2025). Myth of the digital economy: can it continually contribute to a low-carbon status and sustainable development? *Environ. Impact Assess. Rev.* 110:107688. doi: 10.1016/j.eiar.2024.107688

Mwesiumo, D., Halfdanarson, J., and Shlopak, M. (2022). Navigating the early stages of a large sustainability-oriented rural tourism development project: lessons from Træna, Norway. *Tour. Manag.* 89:104456. doi: 10.1016/j.tourman.2021.104456

Nagle, F., Seamans, R., and Tadelis, S. (2025). Transaction cost economics in the digital economy: a research agenda. *Strateg. Organ.* 23, 351–365. doi: 10.1177/14761270241228674

Pang, J., Jiao, F., and Zhang, Y. (2022). An analysis of the impact of the digital economy on high-quality economic development in China—a study based on the effects of supply and demand. *Sustainability* 14:991. doi: 10.3390/su142416991

Philip, L., and Williams, F. (2019). Remote rural home-based businesses and digital inequalities: understanding needs and expectations in a digitally underserved community. *J. Rural. Stud.* 68, 306–318. doi: 10.1016/j.jrurstud.2018.09.011

Pillay, M., and Rogerson, C. M. (2013). Agriculture-tourism linkages and pro-poor impacts: the accommodation sector of urban coastal KwaZulu-Natal, South Africa. *Appl. Geogr.* 36, 49–58. doi: 10.1016/j.apgeog.2012.06.005

Pitrova, J., Krejíi, I., Pilar, L., Moulis, P., Rydval, J., Hlavatý, R., et al. (2020). The economic impact of diversification into Agritourism. *Int. Food Agribusin. Manag. Rev.* 23, 713–734. doi: 10.22434/IFAMR2020.0076

Quaglione, D., Crociata, A., Agovino, M., and Iaia, L. (2020). Cultural capital and online purchase of tourism services. *Annals of Tourism Research*, 80, 102797. doi: 10.1016/j.annals.2019.102797

Roberts, E., and Townsend, L. (2016). The contribution of the creative economy to the resilience of rural communities: exploring cultural and digital capital. *Sociol. Rural.* 56, 197–219. doi: 10.1111/soru.12075

Rogerson, C. M. (2012). Strengthening agriculture-tourism linkages in the developing world: opportunities, barriers and current initiatives. *Afr. J. Agric. Res.* 7, 616–623. doi: 10.5897/ajarx11.046

Shen, Y., and Hu, G. (2024). How does digital inclusive finance improve rural economic resilience? Evidence from China. *Digit. Econ. Sustain. Dev.* 2:35. doi: 10.1007/s44265-024-00035-4

Shen, C., Wu, X., Shi, L., Wan, Y., Hao, Z., Ding, J., et al. (2025). How does the digital economy affect the urban–rural income gap? Evidence from Chinese cities. *Habit. Int.* 157:103327. doi: 10.1016/j.habitatint.2025.103327

Streifeneder, T. (2016). Agriculture first: assessing European policies and scientific typologies to define authentic agritourism and differentiate it from countryside tourism. *Tour. Manag. Perspect.* 20, 251–264. doi: 10.1016/j.tmp.2016.10.003

Tew, C., and Barbieri, C. (2012). The perceived benefits of agritourism: the provider's perspective. *Tour. Manag.* 33, 215–224. doi: 10.1016/j.tourman.2011.02.005

Wang, H., Hu, X., and Ali, N. (2022). Spatial characteristics and driving factors toward the digital economy: evidence from prefecture-level cities in China. *J. Asian Finance Econ. Bus.* 9, 419–426. doi: 10.13106/jafeb.2022.vol9.no2.0419

Wang, W., and Mei, T. (2024). Research on the effect of digital economy development on the carbon emission intensity of agriculture. *Sustainability* 16. doi: 10.3390/su16041457

Wang, J., Xia, L., Zhou, F., Chen, C., and Zhu, Q. (2023). Impacts of the integrated development of agriculture and tourism on sustainable development of agriculture – based on provincial data of China from 2008 to 2019. *Pol. J. Environ. Stud.* 32, 3825–3843. doi: 10.15244/pjoes/163566

Wang, J., and Zhou, I. (2021). The effect of integrated development of agriculture and tourism on agricultural ecological efficiency. *J. Hunan Agric. Univ.* 22, 50–56. doi: 10.13331/j.cnki.jhau(ss).2021.02.007

Wei, X., Zhang, J., Lyulyov, O., and Pimonenko, T. (2023). The role of digital economy in enhancing the sports industry to attain sustainable development. *Sustainability* 15, 1–21. doi: 10.3390/su151512009

Ye, L. (2025). Digital economy and high-quality agricultural development. *Int. Rev. Econ. Finance* 99:104028. doi: 10.1016/j.iref.2025.104028

Yin, S., and Yu, Y. (2022). An adoption-implementation framework of digital green knowledge to improve the performance of digital green innovation practices for industry 5.0. *J. Clean. Prod.* 363:132608. doi: 10.1016/j.jclepro.2022.132608

Yuan, K., Hu, B., Li, X., Niu, T., and Zhang, L. (2023). Exploration of coupling effects in the digital economy and eco-economic system resilience in urban areas: case study of the Beijing-Tianjin-Hebei urban agglomeration. *Sustainability* 15:258. doi: 10.3390/su15097258

Zhang, H., Gu, L., Gu, L.-W., and Zhang, Y. (2011). The evaluation of tourism destination competitiveness by TOPSIS & information entropy - a case in the Yangtze River Delta of China. *Tour. Manag.* 32, 443–451. doi: 10.1016/j.tourman.2010.02.007

Zhang, Y., and Yang, J. (2025).Research on the action mechanism and realization approaches of digital empowerment for the integration of agriculture, culture and tourism in the theoretical perspective of spatial production. *Journal of Yunnan Minzu University (Philosophy and Social Sciences Edition)*, 42, 167–173. doi: 10.13727/j.cnki.53-1191/c.20250702.001

Zhao, T., Zhang, Z., and Liang, S. (2022). Digital economy, entrepreneurship, and high-quality economic development: empirical evidence from urban China. *Front. Econ. China* 17:15. doi: 10.3868/s060-015-022-0015-6