



Synergistic Characteristics of the Digital Economy and High-Quality Tourism Development: Evidence from 31 Provinces in China Based on the Entropy Weight Method and Coupling Coordination Model

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Abstract. With the rapid expansion of the global digital economy, the high-quality evolution of the tourism sector is facing new challenges. Research that explores the interaction between the progress of the digital economy and the basic mechanisms of high-quality tourism development and combined coordination is of great academic and practical value. In this study, we will empirically examine the high-quality development level of China's tourism industry by utilising the entropy measurement method and the sugar content level model. Utilizing national panel data spanning from 2015 to 2024, the research assesses the overall developmental trajectory and key influencing factors. The findings indicate that: (1) From 2015 to 2024, both the digital economy and high-quality tourism development levels showed a steady upward trend, experiencing a brief dip in 2020 due to external shocks before rebounding strongly, forming a symbiotic situation of mutual drive and support. (2) The coupling coordination degree of the two has gradually increased from "severe imbalance" to "high-quality coordination," rising from 0.100 in 2015 to 0.995 in 2024, undergoing a complete evolution, with 2021 as the key turning point for the system to enter a virtuous cycle. In response, this study proposes strengthening digital infrastructure, promoting business innovation, and optimising policy coordination to advance the synergistic development of the two further.

Keywords: digital economy, high-quality development of tourism, coupling coordination, entropy method, China.

1 Introduction

Sustainable development within the digital economy and its deep integration into the tourism sector have become one of the main incentives that contribute to the development of tourism quality.[1]. At present, the sustainable development of the digital economy contributes to the fusion of tourism with digital technologies and actively stimulates tourism, thus becoming a new catalyst for the growth of the tourism industry. In parallel, the Chinese tourism sector has fully recovered and is in a crucial phase of

transition towards high-quality development. As the global tourism industry gradually recovers, China has become the main engine of the recovery of the world tourism landscape due to its unique political stability and its vitality in the market. The introduction of the "14th Five-Year Plan for Tourism Development" [2] and the "14th Five-Year Plan for Digital Economy Development" [3] promotes the coordinated development of the digital economy and tourism from theory to practice; however, the internal mechanisms and optimization paths for their coordinated development require further exploration.

Given the current achievements of research, scientists fundamentally explore the synergistic connection between the digital economy and the qualitative development of the tourism industry from the following three perspectives. First, there is a reasonable mechanism between the digital economy and the qualitative development of the tourism industry. Tian, FF, Weng and GM realized that digitalization could gradually increase the diversification of tourism[4]; Chen Lingling and others believe that digital technology can boost the operational efficiency of tourism and contribute to the modernisation of the tourism industry[5]; Wu Dandang and others believe that there is an important spatial relationship between the digital economy and the qualitative development of tourism[6]; Marijun and Aoye believe that there exists a non-linear "inverted U-shaped" association between the digital economy and the qualitative advancement of the tourism industry.[7]. Second, this constitutes the primary determinant that the digital economy affects the development of high-quality tourism. Tang, H and others found that the impact of the digital economy on tourism development in neighboring cities can be created by the effect of a spaceship[8]; Wu Dandan and others used empirical studies of the panel gradual transition regression model for exploration, showing that the digital economy promotes the advancement of tourism technology, increasing the total efficiency of tourism factors[9]; Wang Jinwei and others found that the level of coordination of the coupling between two economic forces, social and labor, jointly promoting the level of scientific research, tertiary industrial labor and the level of transportation are the main driving factors[10]; Yuan Huai'ai and others said that the digital economy mainly promotes the development of high-quality tourism by reducing operating costs, increasing the level of technological innovation and improving public services[11]. The third is the guiding mechanism and the path of implementation of the digital economy, which contributes to the development of high-quality tourism. Yu, M., etc. found that the digital economy is changing and improving the structure of the tourism industry through industrial digitalization and digital industrialization[12]; Polukhina and A and others believe that the essence of tourism digitization is to meet the needs of tourists and foster innovative business models and emerging revenue and value streams[13]; Liu, HN and others believe that population density, consumption costs, and research and development are important drivers of cooperation, and the interaction between the level of urbanization and other factors tends to weaken the level of association[14]; Cai Chaoyue and others believe that the digital economy stimulates the development of tourism significantly through three components: digital foundational facilities, development of the digital industry and financing for digital integration[15]; Ma Benbin and others believe that they provide sustained and stable symbiotic conditions and form the foundation for the integration of the digital economy and the tourism

industry.[16]; Yan Wei, from the perspective of the technological economic paradigm, believes that the digital economy empowering high-quality tourism development is a progressive evolution across the three dimensions of 'technological system structure-economic industry structure-social institutional structure'[17].

In summary, the existing research still has certain limitations: ① Most existing studies focus on analysing unidirectional influence mechanisms, with few scholars systematically quantifying the dynamic evolution characteristics of their coupling and coordination. ② Previous surveys did not have systematic experimental control based on the national council's big data, which prevented the creation of evidence-based national policies. With this in mind, the present research applies the entropy weighing method and the unified adjustment model to study the general development of the digital economy and the development of high-quality tourism based on national dashboard data from 2015 to 2024, and provides a scientific basis for creating a national tourism digital policy framework for innovation, which carries profound theoretical and practical implications.

2 Research Design

2.1 Research Area and Data Sources

Given that the indicator data for 2025 remains unreleased, this study focuses on the developmental levels of the digital economy and high-quality tourism within China's 31 provincial administrative units (excluding Hong Kong, Macao and Taiwan). The research spans a ten-year period from 2015 to 2024, aiming to uncover the co-evolutionary trends characterizing these two systems through longitudinal panel data. The primary dataset is synthesized from the annual reports of the National Bureau of Statistics, the Statistical Bulletin of the Ministry of Culture and Tourism, and the Communications Industry Statistical Bulletin issued by the Ministry of Industry and Information Technology between 2015 and 2024. Additionally, supplementary details for specific indicators are sourced from local statistical bureaus and specialized industry publications. To guarantee the authority and continuity of the dataset, all sources have been rigorously verified, thereby providing solid empirical support for the subsequent analytical processes.

2.2 Research Methods

2.2.1 Entropy Weight Method.

The entropy weighting method is a loading technique that aims to measure the weight of each indicator from the data. And it is often used in classifications, which include many indicators. The entropy method is based on the principle of entropy data and is weighted by calculating the level of distribution of the index. The specific procedures are as follows:

Standardisation: Let the original data matrix be $X=(x_{ij})_{n \times m}$, where n is the quantity of samples and m is the quantity of indicators. To avoid problems in subsequent

calculations caused by zero values after standardisation, the results are usually shifted, with a shift distance of 0.0001.

Positive indicators:

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

Negative indicators:

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

Weight of calculation indicators:

$$P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^n x'_{ij}} \quad (3)$$

Calculate information entropy:

$$e_j = -k \sum_{i=1}^m (P_{ij} \ln P_{ij}), \text{ generally taken } k = \frac{1}{\ln m} \quad (4)$$

Calculate the coefficient of variation:

$$g_j = 1 - e_j \quad (5)$$

Calculate indicator weights:

$$w_j = \frac{g_j}{\sum_{j=1}^n g_j} \quad (6)$$

The final score is obtained by weighted summation of the values after standardisation and translation according to the index weights:

$$F_i = \sum_{j=1}^n w_j x'_{ij} \quad (7)$$

2.2.2 Coupling Coordination Model.

Coupling characterizes the mutual interaction among two or more systems. by interacting, while coordination focuses on the appropriate and harmonious relationship between systems or elements in a system. The level of articulation coordination is a complete indicator to measure whether the relationship between some systems is developing in coordination or not, and the corresponding formula is provided below:

$$G = \left[\frac{c_1 c_2}{(c_1 + c_2 / 2)^2} \right]^{\frac{1}{2}} \quad (8)$$

$$D = \sqrt{G \times T}, \quad T = \alpha C_1 + \beta C_2 \quad (9)$$

Among them, $\alpha + \beta = 1$; G denotes the coupling degree between systems, T denotes the integrated assessment index; C_1 , C_2 are the comprehensive index scores of the digital economy and high-quality tourism development systems, respectively, and α , β are the weights of the two systems; D represents the degree of coupling, with a value range of $[0,1]$. The values of D and the coupling coordination degree are shown in Table 1.

Table 1. Categorization Rules for Coupling Coordination

Coupling Coordination Degree D	Coordination level	Degree of coupling coordination
[0.0-0.1)	1	Extreme Imbalance
[0.1-0.2)	2	Severe Imbalance
[0.2-0.3)	3	Moderate Imbalance
[0.3-0.4)	4	Slight Imbalance
[0.4-0.5)	5	Near Imbalance
[0.5-0.6)	6	Barely Coordinated
[0.6-0.7)	7	Primary Coordination
[0.7-0.8)	8	Intermediate Coordination
[0.8-0.9)	9	Good Coordination
[0.9-1.0)	10	Excellent Coordination

2.3 Construction of the Index System

This indicator system refers to previous research results and, after supplementation and improvement, establishes two systems for the high-quality development of the digital economy and the tourism industry. It covers eight dimensions: digital infrastructure[18], industrial digitalisation[18], digital innovation capability[10], industrial scale and efficiency[10], service quality and experience[18], industrial structure and diversification, green and sustainable development[19], and shared development[19], systematically depicting the empowerment foundation of digital technology for the tourism industry and the development achievements of the tourism industry as shown in Table 2. The construction of the indicator system strictly follows the following three principles: ① Policy principle. By referring to national policy documents and official explanations regarding the evolution of the digital economy and the tourism industry, it ensures that the indicators are aligned with national strategic guidance. ② Principle of authority. This study examines the design of digital economy indicator systems and high-quality development indicator systems for the tourism industry by various scholars, so as to guarantee the rigor and scientific soundness of the indicator systems. ③ Practicality principle. Based on existing indicator systems, priority is given to continuously measurable indicators available from official sources, improving the current indicator system. In terms of weight allocation, the entropy method is utilized to objectively determine weights for each indicator based on the dispersion level of panel data from 2015 to 2024, thus guaranteeing the scientific validity and dependability of the evaluation outcomes.

Table 2. Index System and Weight Determination for the High-Quality Development of the Digital Economy and Tourism

Primary indicator	Number	Secondary indicator	Level 3 Indicator	Unit	Indicator attributes	Weight
Digital economy	X1	Digital infrastructure	Internet access penetration rate	%	Positive	0.029
	X2		Mobile ownership penetration rate	per 100 people	Positive	0.024
	X3		Mobile payment penetration rate	%	Positive	0.019
	X4		Number of IoT terminal access users	hundreds of millions of households	Positive	0.039
	X5		Fixed Internet broadband access users	Ten thousand households	Positive	0.028
	X6	Industrial digitalisation	Mobile data traffic per internet user	100 million GB	Positive	0.042
	X7		Count of internet users	hundreds of millions of people	Positive	0.028
	X8		E-commerce transaction volume	100 million yuan	Positive	0.024
	X9		Number of computer users per hundred people	platform	Positive	0.030
	X10		R&D full-time equivalent staff	man-years	Positive	0.045
High-quality	X11	Digital innovation capability	Number of information technology enterprises	piece	Positive	0.053
	X12		Number of enterprises with e-commerce transaction activities	piece	Positive	0.076
	X13		Number of patent grants in the digital economy sector	Ten thousand pieces	Positive	0.043
	Y1	Industry scale and efficiency	Value added of the tourism and related industries	100 million yuan	Positive	0.026

development of the tourism industry	Y2		Total expenditure of domestic tourists	100 million yuan	Positive	0.029
	Y3		Per capita spending of domestic tourists	Yuan	Positive	0.022
	Y4		Number of domestic travellers	millions of people	Positive	0.025
	Y5		Quantity of star-rated hotels	piece	Positive	0.048
	Y6	Service quality and experience	Count of star-rated scenic attractions	piece	Positive	0.027
	Y7		Online travel complaint resolution rate	%	Positive	0.024
	Y8		Smart service coverage rate of 4A/5A scenic spots	%	Positive	0.028
	Y9		Total volume of inbound tourists	ten thousand person-times	Positive	0.024
	Y10	Industrial structure and diversification	Foreign exchange earnings from international tourism	hundred million US dollars	Positive	0.031
	Y11		Revenue from high-end tourism products	100 million yuan	Positive	0.034
	Y13		Household waste collection volume	ten thousand tonnes	Positive	0.020
	Y14	Green and sustainable development	Number of harmless treatment plants	piece	Positive	0.038
	Y15		Urban park green space extent	ten thousand hectares	Positive	0.026
	Y16		Green coverage ratio of built-up districts	%	Positive	0.031
	Y17		Total annual passenger transport volume	hundreds of millions of people	Positive	0.025
	Y18	Shared development	Art performance showings	Ten thousand sessions	Positive	0.013
	Y19		Number of public toilets per ten thousand people	piece	Positive	0.049

3 Empirical Analysis

3.1 Analysis of the Comprehensive Development Level of Digital Economy and High-quality Tourism Development from 2015 to 2024

By feeding the corresponding indicator data of the digital economy and high-quality tourism development from 2015 to 2024 into Equations (1)–(7), the integrated development level of both sectors can be computed (Fig. 1).

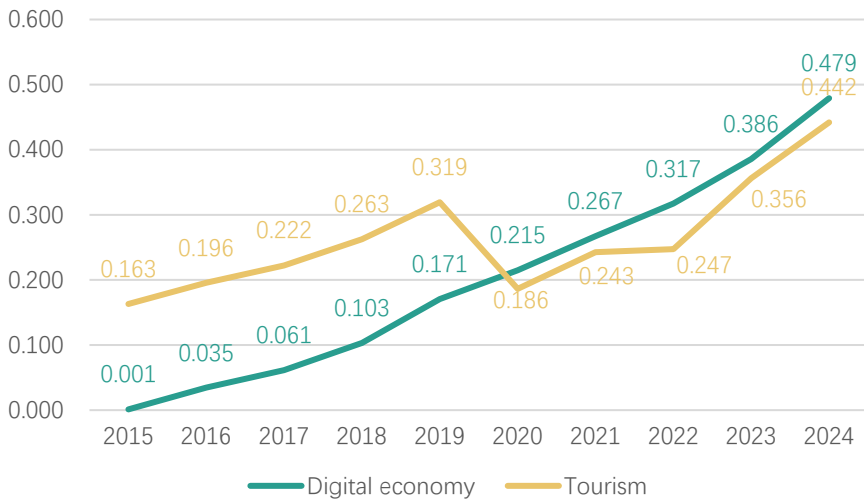


Fig. 1. Comprehensive development level of the digital economy and tourism industry

In general, the integration point of the digital economy shows a constantly growing development from 0.001 in 2015 to 0.479 in 2024; the integration point in the tourism sector shows a fluctuating trend of 0.163 in 2015 to 0.442 in 2024. Although both sectors have a general upward trend, the tourism sector is more sensitive to external environmental factors.

In terms of tourism, the overall trend from 2015 to 2019 was upward, during which the tourism market continued to expand, and the implementation of the cultural and tourism integration policy promoted industrial upgrading[20], leading to strong tourism demand. From 2019 to 2020, the development level of the tourism industry was affected by the COVID-19 pandemic, with travel activities restricted, scenic spots closed, and the industry chain brought to a standstill, resulting in a sharp decline in development. From 2020 to 2024, the tourism industry's development level showed a gradual recovery trend, with the comprehensive score rising from 0.186 to 0.442, particularly notable in 2022–2023, benefiting from the optimisation of epidemic prevention policies, support from the "14th Five-Year Plan" cultural and tourism industry recovery policies, and the popularisation of new formats such as "cloud tourism" and "smart scenic spots" empowered by digital technology[21], which promoted a rapid market rebound in tourism.

In terms of the digital economy, it has maintained steady growth from 2015 to 2024, reflecting the long-term benefits of improved digital infrastructure and accelerated industrial digital transformation, and it has also been an important force in supporting economic resilience during the pandemic.

In general, there is a clear connection between the development of the digital economy and the tourism industry. The digital economy fuels the high-quality development of tourism, which in turn drives the advancement of the digital economy.

3.2 Analysis of the Coupling and Coordination Characteristics of Digital Economy and High-Quality Tourism Development from 2015 to 2024

Overall, the matching degree between the digital economy and high-quality tourism development showed a fluctuating upward trend from 2015 to 2024. The level of coordination gradually expands from "serious imbalance" in 2015 to "high-quality coordination" in 2024, reflecting the continuous improvement of coordinated development. As shown in Figure 2 and Table 3, this process can be divided into three steps.

Phase 1: From 2015 to 2019, it was a transition period from imbalance to coordination, and the combined coordination increased from 0.100 to 0.66. The level of adjustment changed from "severe imbalance" in 2015 to "primary coordination" in 2019. At this stage, support for the digital economic infrastructure was accelerated, and indicators such as the level of internet penetration and mobile payment coverage were rapidly expanded, which formed the basis for the digital transformation of the tourism industry. Meanwhile, innovative business models such as "smart landscape places" and "cultural online tourism" have begun to develop, which evolve from early collaboration between the digital economy and the tourism sector to joint integration.

Table 3. Coupling Scores of the 'Digital Economy-Tourism High-Quality Development System' from 2015 to 2024

Year	Coupling coefficient C value	Coordination Index T-value	Coupling coordination degree D value	Coordination level	Coupling coordination level
2015	1.000	0.010	0.100	2	Severe Imbalance
2016	0.975	0.102	0.315	4	Slight Imbalance
2017	0.971	0.176	0.413	5	Near Imbalance
2018	0.970	0.290	0.530	6	Barely Coordinated
2019	0.975	0.458	0.669	7	Primary Coordination
2020	0.750	0.270	0.450	5	Near Imbalance
2021	0.949	0.423	0.663	7	Primary Coordination
2022	0.931	0.482	0.670	7	Primary Coordination
2023	0.997	0.744	0.861	9	Good Coordination
2024	1.000	0.990	0.995	10	Excellent Coordination

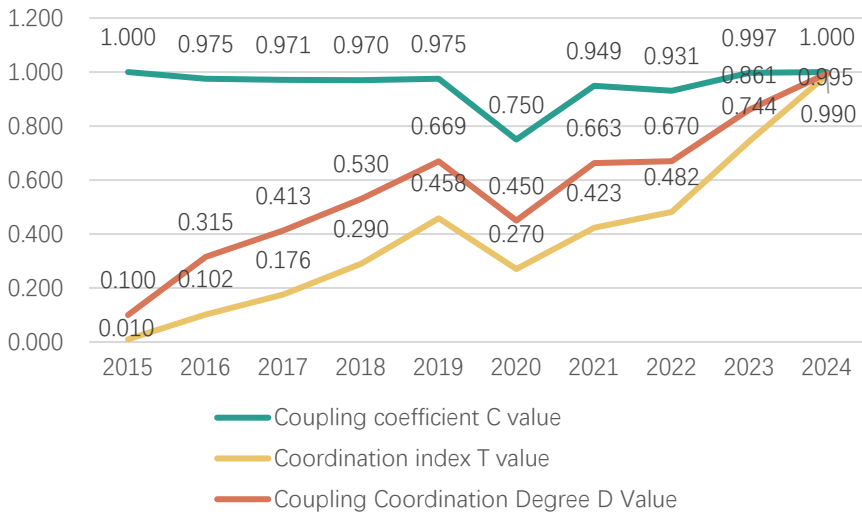


Fig. 2. Coupling and coordination analysis results of the 'Digital Economy-Tourism Industry High-Quality Development System' from 2015 to 2024

Phase Two: In 2020, the coordination between the two regressed to a 'near imbalance' state, with the coupling coordination level dropping from 0.669 to 0.450. This stage was impacted by the global spread of the COVID-19 pandemic, causing offline scenarios in the tourism industry to come to a complete halt, with core indicators such as domestic travel numbers and tourism revenue experiencing a sharp decline. Meanwhile, the digital economy showed resilience through models such as remote work and online consumption, but it was difficult to completely offset the decline in tourism in the short term, disrupting the rhythm of their coordination.

Phase three: 2021-2024, the coupling coordination level of the two increased continuously from 0.663 to 0.995, and the coordination level rose from 'primary coordination' to 'high-quality coordination'. During this phase, epidemic prevention and control policies were gradually optimised, and tourism consumption demand was rapidly released[22]. At the same time, the successive introduction of related policies promoted the deep integration of the tourism industry and the digital economy, with new formats such as 'cloud tourism' and 'immersive cultural tourism' becoming growth engines. The strength of the connection between the two continued to increase, and their collaborative relationship entered a high-quality adaptation stage.

Overall, the coordinated development of the digital economy and high-quality tourism is closely related to the macro environment, policy guidance, and technological empowerment. The volatility in 2020 confirmed the short-term influence of external shocks on system synergy, whereas the subsequent rapid recovery demonstrated the supportive function of the digital economy for tourism and the long-term merits of industrial integration. Looking forward, with the sustained penetration of digital technology and the escalation of cultural and tourism consumption, the two systems are

expected to further enhance their coordination under the framework of "high-quality coordination," establishing a more resilient industrial development ecosystem.

4 Research Findings and Discussion

4.1 Research Findings

This study uses the entropy method and communication coordination model to innovatively build a dual-system evaluation index system for the digital economy and qualitative tourism development, and systematically analyzes the changing model of their integrated development level and communication coordination degrees based on 31 provincial-level panel data across the country from 2015 to 2024. According to the study, (1) From 2015 to 2024, the development levels of the two systems maintained a continuous upward trend. The development of the digital economy rose from 0.001 to 0.479, and tourism development rose from 0.163 to 0.442. Tourism experienced a brief setback in 2020 due to external shocks but showed a strong rebound, with both showing an overall pattern of mutual support and coordinated progress. (2) The coupling coordination level between the two systems improved progressively from extreme imbalance in 2015 to high-quality coordination by 2024, undergoing an evolution of disorder-primary coordination-near imbalance-primary coordination-high-quality coordination. Notably, 2021 was a critical inflection point, with the system formally entering the primary coordination stage, after which the pace of synergistic development between the two accelerated significantly.

4.2 Discussion

This study found a significant positive relationship between the two systems, which is consistent with the conclusions of scholars Tian, FF, Weng, GM, Chen Linlin, and others [4, 5]. However, the rapid rebound of both after 2020 in this study differs from the "inverted U-shaped" non-linear relationship proposed by Ma Lijun and Ao Ye [7]. This may be because their research was conducted earlier and did not cover the period when digital technology strongly supported the recovery of the tourism industry during the pandemic, reflecting the impact of the time dimension on research conclusions.

This study finds that the overall coupling coordination degree shows an upward trend, which is similar to the views of scholars such as Wang Jinwei and Cai Chaoyue [10, 15]. The brief decline in coupling coordination in 2020 reflects the short-term disturbance of the system's coupling coordination relationship due to the influence of the external environment.

5 Conclusion

5.1 Research Summary

This study will systematically examine the co-evolving characteristics of the digital economy and the development of high-quality tourism by adopting the entropy weighting method and a combined coordination model for the period from 2015 to 2024. According to research, the development of the digital economy and high-quality tourism does not form a simple unilateral authorization relationship, but rather forms a symbiotic system characterized by two-way guidance and development up and down. The digital economy serves as a driving force for tourism recovery and efficiency improvement, whereas the upgrading of tourism demand offers a vital scenario for the innovative application of digital technologies. The synergistic linkage between the two systems improved continuously from serious incoordination in 2015 to high-level coordination in 2024, with 2021 serving as a critical inflection point that facilitated a marked enhancement in system coordination.

5.2 Recommendations

Strengthen digital infrastructure. Increase investment in digital infrastructure, including 5G and big data centres, to solidify the hardware conditions for the digital economy to empower the tourism industry.

Promote business model innovation. Encourage the development of new tourism formats, for instance, smart tourism and immersive experiences, and expand tourism consumption scenarios through digital technology.

Optimise policy coordination. Establish cross-departmental coordination mechanisms, plan the high-quality development of the digital economy and tourism industry in an integrated manner, and monitor the implementation of relevant policies.

5.3 Limitations and Future Prospects

This study has certain limitations: first, due to the availability and continuity of publicly accessible statistical data, the indicator system constructed in this paper cannot fully cover all indicators; second, the long-term impact of external shocks such as public emergencies has not been fully considered, resulting in insufficient characterisation of the dynamic adaptability of the tourism industry's recovery and digital economy empowerment in the post-pandemic era. In view of this, future research could be expanded in the following directions: first, expand the spatial dimension of the study by adding heterogeneous research by regions and provinces on top of national-level analysis, revealing differences in collaborative evolution and driving logic among different spatial units; second, improve research data, as subsequent studies could attempt to integrate macro statistical data, micro-enterprise data, and micro-survey data to address the analytical limitations of single macro data and enrich the indicator system; third, explore the long-term mechanisms of digital economy and high-quality development of the tourism industry to provide more forward-looking references for policy formulation.

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