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Spatio-temporal evolution of Supply-Demand-Support system coupling coordination and SDS' influencing factors in Chinese cultural tourism

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The development of quality and efficiency improvement in cultural tourism have become hot topics of academic discussion in China. Based on the coupling coordination theory, this study constructs a coupling coordination model of product supply and economic development of cultural tourism, calculates the coupling coordination level of 31 provinces in China, and then analyzes the spatiotemporal evolution of the coupling coordination level, and then analyzes its influencing factors according to the GTWR model. The results are as follows: (1) From 2007 to 2020, the global spatial positive correlation between the coupling and coordinated development ability of cultural tourism supply-demand-support system is prominent, the dynamics of local space is strong, and the cooperation ability shows the characteristics of strong east and weak west. (2) The ability of coupling and coordinated development decreases from east to west, but the development advantage of southwest China is obvious, among which the self-activity degree of northwest region is low, while southwest region is the highest. The development of cultural tourism maintains a relatively stable development trend in Southwest. (3) The degree of openness has a large trend of influencing ability, while the development of other five influencing factors maintains a relatively stable ability. In the stage of imbalanced development, the influence of openness, scientific and technological support, and potential consumption has decreased, while the influence of the influencing factors of household consumption and industrial support has remained unchanged, and the influence of economic security has increased. Recognize and explore cultural tourism as a "community", put forward specific countermeasures and suggestions, and realize the sustainable and healthy development of cultural tourism product supply and economic development. The article enriches the theory of the supply-demand-support system of cultural tourism, and also contributes Chinese wisdom to the sustainable development of cultural tourism.

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Introduction

Due to the unique attributes of its products, cultural tourism provides important spiritual products and spiritual sustenance for the needs of the people for a better life, and has become an indispensable demand in life. Similarly, cultural tourism is a dynamic industrial system, and according to the results published on the official website of the World Travel & Tourism Council (WTTC), “the proportion of young people employed in the tourism industry is higher than that of the economy as a whole, indicating that the tourism industry is more dynamic in the economy and society as a whole”, and similarly, the ability of tourism to contribute to economic development has been increasing, and the contribution of tourism to GDP increased by 1 trillion US dollars in 2021 (an increase of 21.7%). Since the reform and opening up, the development of China’s tourism industry has changed from the inbound tourism market to the diversified markets such as the domestic market, the outbound market and the inbound market, which is divided into four stages: the initial stage of modern tourism, the stage of domestic tourism cultivation, the stage of tourism development, and the stage of new normal tourism (Zhang Chengming et al., 2019). Over the years, the supply of cultural tourism products has kept up with the dynamics of social development and caught up with the hot spots of market consumption, and the product system of Internet celebrities and hot spots has been emerging. In the process of cultural tourism development, how to realize the hot spot of product supply and the sustainability of economic development has become a key issue that needs to be solved urgently to achieve the sustainable development of cultural tourism.

Cultural tourism has always been a hot topic of discussion in academia and industry, the initial development is because of its economic attributes by the industry’s attention, and then in the academic community to carry out extensive exploration and research, but there are still certain cognitive differences in the concept of cultural tourism, from tourism culture to cultural tourism, for a period of time the two concepts of tourism culture and cultural tourism are equivalent to research. From the perspective of the international perception of the concept of cultural tourism, in 1985, the World Tourism Organization (UNWTO) defined the meaning of the concept of cultural tourism from two levels: broad and narrow, in a broad sense, cultural tourism is “to meet the various needs of individuals to participate in all activities to increase knowledge, expand horizons, and improve the environment (the purpose of cultural tourism); In a narrow sense, cultural tourism is “the activities carried out by people in order to meet basic cultural needs, including folk tourism, historical site tourism, festival tourism, pilgrimage tourism, performing arts tourism, etc.” Its prominent purpose is mainly to define it in terms of the purpose of the tourist’s experience. The International Charter for Cultural Tourism (1999) elaborates on the meaning of cultural tourism, and regards culture itself and the environment in which it is located as the core of cultural tourism and the cultural environment includes not only historical and cultural landscape resources, but also local residents’ customs, lifestyles and even natural landscape resources of tourist destinations. Cultural tourism is defined as “tourism that focuses on the cultural and cultural environment, including the landscape, values and lifestyle of the destination, heritage, visual and performing arts, industry, traditions and leisure activities of the local population or host community” (Long, 2014). In 1991, the European Association for Tourism and Leisure Education (ATLAS) defined cultural tourism as “all non-profit activities in which people go to the location of cultural resources such as ancient ruins, artistic and cultural performances, and artistic performances in order to obtain or satisfy their own cultural needs”. Smith (1997) defines

cultural tourism as “a picture or local feature of a way of life that is disappearing in human memory, a remnant of that way of life”. Cultural tourism is an activity that aims to experience, feel, perceive, and engage in artistic activities. Cultural tourism refers to the behavioral process of perceiving, understanding, and observing the specific content of human culture through tourism (Xiong Zhengxian & Wu Liwei, 2016), and is the movement of people from their daily places of residence to the cultural landscape in order to obtain new information and experience to meet their cultural needs (Wang Kelin et al., 2013). Cultural tourism is a tourism activity rich in cultural characteristics and cultural orientation, and there are two kinds of “cultural tourism” in the broad sense and the narrow sense.

Culture and tourism have always been inextricably linked, and cultural landscapes, attractions and activities provide an important incentive for tourism, and tourism activities themselves can generate culture. The similarities and differences between the terms “cultural industries” and “creative industries” are followed by the fact that they share the same characteristics in substance (Lee et al., 2014). Milestone further expands the scope of the creative industries, referring to the cultural industry and the art industry as the creative industry (Milestone & Katie, 2016). Richards G. (Kim & Ritchie, 2014) argues that the shift from tangible to intangible competitive advantage continues and presents a trend towards relational tourism based on creativity and embedded knowledge. Booyens I. (Booyens & Rogerson, 2015) believes that cultural and creative tourism is a field that should be continuously expanded, and the economic effect of integration has not been fully utilized, and put forward suggestions such as developing a comprehensive creative tourism product portfolio and planning the development of creative regions. Booyens I. (Booyens & Rogerson, 2016) pointed out that the connection between tourism projects and other related industries, the improvement of cultural and creative colors, and the emphasis on hierarchy and taste are constantly becoming the characteristics of the tourism industry, and its Chinese creativity and taste have become the top priority of tourists. Ali F. (Ali F. et al., 2016) proposes that the experience of creative travelers is a good predictor of their memory, satisfaction, and behavioral intent. Kim J.H. (Kim & Ritchie, 2014) established the cross-cultural validity of the Memorable Travel Experience Scale, proposing that MTES can often be used to assess an individual’s memorable travel experience in a cross-cultural setting. This study takes cultural tourism as a system, and conducts in-depth research on its internal supply, demand and support subsystems, evolution laws and influencing factors. The development of culture and tourism is a difficult process to truly move towards the systematic development of cultural tourism, and the realization of this process needs to identify the common attributes of culture and tourism, and expand the connotation and extension of the common attributes.

System coupling itself is a physical concept, which refers to the phenomenon that two or more systems interact with each other through mutual movement and interaction, and finally achieve synergy (Du Xianghong, 2014). The theoretical basis of the concept of coordination degree stems from the synergy theory proposed by Hermann Haken in the 1970s. The coupling coordination theory can effectively judge the relationship between the two independent systems. The research on the coupling coordination of cultural tourism mainly focuses on the coupling coordination between cultural tourism itself and cultural tourism and other systems. Gunn constantly emphasizes the basic position of the interaction between the two modules of tourism supply and demand in the tourism system (Gunn & Var, 2002). The research process of cultural tourism studies the coupling and coordination

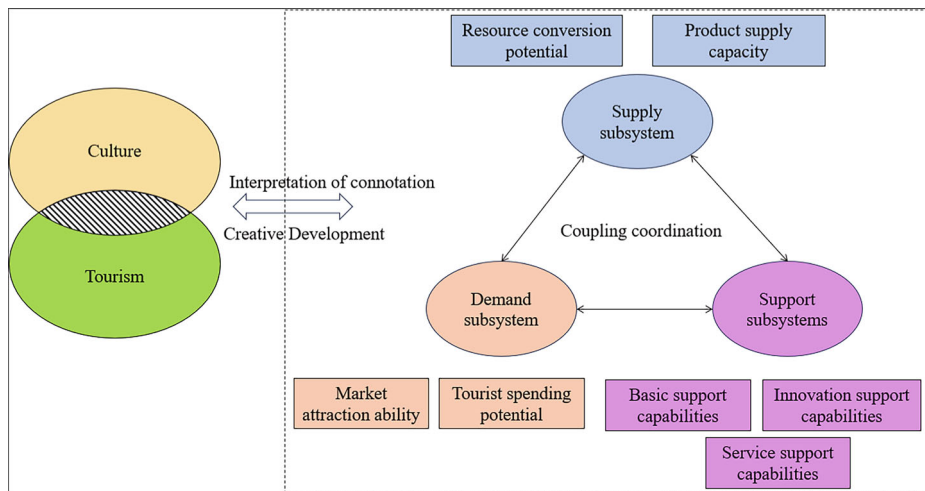


Fig. 1 The theoretical framework of supply and demand and the support system of Chinese cultural tourism.

relationship between the cultural tourism system and other systems. One is based on the coupling and coordination of cultural tourism itself, mainly from the study of the coupling relationship between culture and tourism, to study the coupling and coordination of cultural tourism itself. Wu Bihu divides tourism activities as recreational activities into destination system, travel system, support system and source system (Wu Bihu, 1998). Shi Yan et al. analyzed the coupling and coordinated development relationship between tourism and culture and the corresponding development countermeasures (Shi Yan & Zhan Guohui, 2021). Wu Li et al. studied the coupling and coordination of Chinese culture and tourism, and then analyzed the spatial differences and driving factors of the coupling (Wu Li et al., 2021). The second is based on the coupling and coordination between tourism and other systems, such as culture and ecology. Xu Xiuwen regards cultural tourism as a system, and analyzes its coupling relationship with the coordinated development of the urban economy and the relationship between internal mechanisms. The research results show that from 2014 to 2017, cultural tourism gradually developed and had good coordination (Xu Xiwen, 2018). Hong Xueting et al. studied the coupling relationship between cultural resources and tourism industry, and then analyzed the compensation mechanism (Hong Xueting et al., 2020). It can be seen that the application of the coordination theory in the study of the coupling relationship between culture and tourism and the coupling relationship between cultural tourism and other systems is helpful to the study of the coupling and coordination between the product supply of cultural tourism and economic development.

The development of cultural tourism realizes the further integration and development of the two systems of culture and tourism, mainly through the application of product system, financial system, virtual technology and other means, to cultivate more creative cultural performances, cultural and creative products, cloud tourism, virtual tourism and other formats and product systems, to achieve the overall development of cultural tourism, and enhance the comprehensive competitiveness of cultural tourism development. Firstly, from the connotation of the supply-demand-support system of cultural tourism, it is a system for tourists to engage in cultural tourism activities, including destinations, tourist sources and supporting parts, which complement each other and promote together. Secondly, the main tourist destinations are the main tourist destinations of tourists, and people reflect more cultural needs in the process of tourism activities, no longer taking a single scenic spot (point) as a destination for in-depth participation in the experience, and

paying more attention to regional tourist destinations based on diversified tourist demand experience, which requires the overall development of cultural tourism. Finally, the process of cultural tourism is the process of achieving the goal of spiritual pleasure of tourists, and tourists take the local cultural experience as the main experience perception in the process of carrying out activities, and pay attention to the cognition of regional culture. As a new form of tourism, cultural tourism not only needs to pay attention to the integration of the respective benefits of culture and tourism, but also needs to consider how culture and tourism can play the mutual integration of common attributes and characteristics to maximize economic and social benefits. Taking the research on the spatial-temporal characteristics of the coupling and coordination of the supply-demand and support system of cultural tourism in China from 2007 to 2020 and the influencing factors of the evolution of this spatial-temporal characteristics as an example, this paper constructs the index system and coupling coordination model of the supply-demand and support system of cultural tourism, calculates its spatial-temporal evolution characteristics, and analyzes the influence of six factors such as Degree of openness, Technological development, Potential consumption, Residents' consumption, Industry support and Financial security to the outside world on this spatial-temporal characteristics. The aim is to enrich the theory of the supply-demand-support system of cultural tourism, and also provide Chinese wisdom for the sustainable development of cultural tourism (Fig. 1).

With the continuous development of economy and society, people's research on the maximization of the comprehensive benefits of cultural tourism has become a hot spot of concern, such as the deep integration development of cultural tourism (Liao et al., 2025), the economic development of cultural tourism industry (Wang Kelin et al., 2013), the high-quality development of deep integration of cultural tourism (Song et al., 2025), the digital development of cultural tourism (Xie et al., 2022), the sustainable development of cultural tourism (Wang Xin et al., 2024), and the catalytic role of regional economy (Zhou Jiapin et al., 2025), which can enrich the theoretical knowledge of supply and demand of cultural tourism market. At the same time, driven by the demand of market consumers, the supply of cultural tourism products needs higher-quality production. Therefore, the demand for cultural tourism needs to drive the transformation and upgrading of products, and also promote the rational layout of transportation, accommodation, catering and other industries in the region. At present, cultural tourism has become an important driving force for China's economic and social

development. How to promote the sustainable development of the cultural tourism system has become a key measure to promote regional economic and social development. The existing research mainly focuses on the concept, connotation and case study of culture and tourism, but the quantitative research and systematic research on cultural tourism are relatively weak. This study mainly analyzes the spatial and temporal characteristics of the coupling and coordination of the supply and demand, and support system of Chinese cultural tourism and its influencing factors by constructing 32 factors as the evaluation of the supply demand and support system and 6 main influencing factors, and puts forward the optimization measures for the supply demand and support system.

Indicator system construction and research methods

Construction of the indicator system. From the perspective of the supply side of cultural tourism products, the basic services of tourism include tourism accommodation, tourism catering, tourism entertainment, and tourism shopping, while the cultural industry is manifested in the production of cultural products on the supply side, including content creation and production, cultural communication channels, and cultural auxiliary production (Fan Peng & Yan Xiong, 2022). On the basis of the existing research of Liu Chunji et al. (Liu Chunji et al., 2014), Wang Zhaofeng et al. (Wang Zhaofeng & Xie Jialiang, 2023), Lin Kongtuan, etc. (Lin Kongtuan & Weng Muying, 2014), this paper selects A-level tourist attractions, star-rated tourist hotels, travel agencies, art performance groups, museums and cultural centers as the main cultural tourism products for research, and measures the product supply capacity of cultural tourism. For the measurement of demand, the main domestic tourists, inbound tourists, domestic tourism income, and tourism foreign exchange income are measured (Tang Tuopei et al., 2023). The scale part is not only the measurement of domestic tourists, but also the most commonly used indicator to measure China's inbound tourism demand. Considering the existing public data, the indicators for the economic development of the cultural industry are mainly based on the added value of the cultural industry, due to the revision of the "Classification of Cultural and Related Industries" (2012) in 2012, and the "Statistical Yearbook of Chinese Cultural Relics" (Wang Jiajiao & Liang Dong, 2021) (Table 1).

This study is mainly based on the 'China Cultural Relics and Tourism Statistical Yearbook' (formerly the 'China Tourism Statistical Yearbook'), the 'China Statistical Yearbook' and the tertiary industry statistics, 'China Forestry Statistical Yearbook' and other statistical yearbooks; at the same time, some data of cultural tourism resources are derived from the official website of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the official website of the Ministry of Culture and Tourism, and the official website of the State Administration of Cultural Heritage. Culture and tourism patent data are mainly derived from Culture and tourism patent data mainly come from the official website of the State Intellectual Property Office. (<http://epub.cnipa.gov.cn/>) (Table 1).

From the perspective of the development status of China's cultural tourism supply and demand support system, it is mainly manifested as: The comprehensive benefits of A-level scenic spots continue to play. By the end of 2020, there were 13,332 A-level scenic spots in the country, an increase of 930 from the end of the previous year. According to the 'National Star Hotel Statistics Report 2020', there were 8423 star hotels in China in 2020, which is 28.49% lower than the number of star hotels in 2007, with an average annual decline of 3.30%. It is mainly related to the personalized and diversified needs of market consumption. In 2020, the total number of travel agencies will be 40682, an

increase of 78.56% compared with 2007, with an average annual increase of 5.97%. In 2020, the number of museums in the country will be 5452, an increase of 123.90% compared with 2007, with an average annual increase of 8.39%. The development of China's cultural tourism economy shows a good trend, and the domestic tourism market is steadily rising. The number of domestic tourists was 2.879 billion in 2020, and the domestic tourism revenue was USD 307.876 billion in 2020. From the perspective of the overall development of the product supply and economic development of national cultural tourism, it shows a rapid growth trend and a large change (Table 2).

Research methods

Coupling coordination model. The entropy method (Lei et al., 2021) is used to calculate the weights of 32 indicators of the supply-demand-support system of cultural tourism, determine the weight relationship between the index systems, calculate the comprehensive evaluation value of the supply-demand-support system of cultural tourism, and then calculate its coupling coordination degree. Then, the supply-demand-support system of cultural tourism is divided into specific categories and types, and the change characteristics of its coupling and coordination stage are analyzed.

The specific calculation steps are as follows:

1. Standardize the data of the cultural tourism supply-demand-support system through the method of extreme value, and add 0.00001 when the processing data is 0, so as to prevent the data from being meaningless in the calculation process (Positive / negative indicators). When standardizing the 32 indicator systems, formula (1) is used for the positive indicator and formula (2) is used for the reverse indicator (Wang Xiaotian, 2022).

$$\begin{cases} X'_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} + 0.000011 \\ X'_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} + 0.000012 \end{cases} \quad (1)$$

2. Calculate the proportion of the *i*th regional index in the *n*th year under the *j*th indicator in the 32 index systems of the supply-demand-support system of cultural tourism, *y*-*ij*:

$$Y_{ijn} = x_{ijn} / \sum_{i=1}^m x_{ijn} \quad (0 \leq y_{ij} \leq 1) \quad (2)$$

3. Calculate the entropy value of the *j*th index of the 32-index systems of the supply-demand-support system of cultural tourism, *e*-*j*:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^m Y_{ij} \times \ln(Y_{ij}) \quad (3)$$

4. Calculate the difference value of 32 index systems of the cultural tourism supply-demand-support system according to the entropy value *EJ*:

$$a_j = 1 - e_j \quad (4)$$

5. Calculate the value of the weight *W*_{*ij*}, and the calculation results are detailed in Table 3:

$$W_{ij} = \frac{a_j}{\sum_{i=1}^m a_j} \quad (5)$$

6. The comprehensive evaluation value is multiplied according to the evaluation weights of the 32 indicators of the cultural tourism supply-demand-support system and the values of the corresponding factors, and then the comprehensive evaluation

Table 1 The main evaluation index system of the supply-demand-support system of cultural tourism.

Indicators	Criterion layer	Evaluation factor	Factors	Unit	Positive/negative	
Supply subsystem B ₁	Resource conversion potential X ₁	The number of cultural tourism resources	X ₁₁	piece	+	
		Number of natural tourism resources	X ₁₂	piece	+	
	Product supply capacity X ₂	Number of 5A-level tourist attractions	X ₂₁	piece	+	
		Number of star-rated tourist hotels	X ₂₂	piece	+	
		Number of travel agencies	X ₂₃	piece	+	
		Number of performing arts groups	X ₂₄	piece	+	
		Number of museums	X ₂₅	piece	+	
		Number of cultural centers	X ₂₆	piece	+	
	Demand subsystem B ₂	Market attraction ability X ₃	The growth rate of domestic tourists	X ₃₁	%	+
			The number of inbound tourists	X ₃₂	10,000 people	+
The total number of people in circulation of the library			X ₃₃	10,000 people	+	
Total number of visitors to the museum			X ₃₄	10,000 people	+	
The number of domestic performance audiences of art performance groups			X ₃₅	10,000 people	+	
Tourist spending potential X ₄		Per capita tourism expenditure of domestic tourists	X ₄₁	USD/person	+	
		Per capita tourism expenditure of domestic tourists	X ₄₂	USD/person	+	
		Operating income of cultural market operating institutions	X ₄₃	Dollar	+	
		Information Index	X ₄₄	/	+	
		Support subsystems B ₃	Basic support capabilities X ₅	Rail density	X ₅₁	km/km ²
Highway mileage	X ₅₂			Km	+	
Air transport volume	X ₅₃			10,000 people	+	
The total volume of postal and telecommunications services	X ₅₄			million yuan	+	
Innovation support capabilities X ₆	Number of toilets per 10,000 people		X ₅₅	piece	+	
	Number of cultural tourism patents		X ₆₁	piece	+	
	Number of students enrolled in the arts and culture category/Number of students majoring in tourism		X ₆₂	people	+	
	Cultural and artistic research institutions		X ₆₃	piece	+	
	The amount of investment in cultural undertakings		X ₆₄	Dollar	+	
	Service support capabilities X ₇		Number of legal entities in the catering industry	X ₇₁	piece	+
Average business turnover of accommodation enterprises		X ₇₂	billion US dollars/piece	+		
Distribution density of the retail sector		X ₇₃	piece/km ²	+		
The average turnover of a travel agency		X ₇₄	dollars/piece	+		
The ratio of tourist arrivals to passenger traffic		X ₇₅	%	+		
The proportion of total tourism income in the investment in fixed assets of the tertiary industry		X ₇₆	%	+		

"+" indicates that the evaluation factor is a positive index, and "-" indicates that the evaluation factor is a negative index. For specific data sources, please refer to Annex 1 for the data sources of the main evaluation indicators of the cultural tourism system.

value is obtained after adding them.

$$U_i = \sum_{j=1}^m W_{ij} \times U_{ij} \dots \dots \dots \sum_{j=1}^m W_{ij} = 1 \tag{6}$$

7. Calculation of coupling coordination

Firstly, according to the comprehensive evaluation value of each subsystem of the cultural tourism supply-demand-support system, the coupling relationship of the system, that is, the coupling degree, is calculated, and the specific formula is as follows:

$$C = \left(\frac{U_1 \times U_2 \times \dots \times U_n}{\left(\frac{U_1 + U_2 + \dots + U_n}{n} \right)^n} \right)^{\frac{1}{n}} \tag{7}$$

The larger the coupling degree, the stronger the interaction between the system and the subsystem, and the smaller the coupling degree, the weaker the interaction between the three.

The coupling relationship was modified according to Wang Shujia et al. (Wang Shujia et al., 2021) to modify the coupling coordination model. When n = 3, maxUi is assumed to be U3 for

calculation, and the calculation formula is as follows:

$$C = \sqrt[3]{ \left[1 - \frac{\sqrt{(U_3 - U_1)^2} + \sqrt{(U_2 - U_1)^2} + \sqrt{(U_3 - U_2)^2}}{3} \right] } \times \sqrt[3]{ \frac{U_1}{U_3} \times \frac{U_2}{U_3} } \tag{8}$$

Secondly, according to Eq. (8), the coupling coordination degree between the supply-demand-support system of cultural tourism is calculated to illustrate the coupling coordination relationship of the whole system, that is, the coupling coordination degree, and the specific formula is as follows:

$$\begin{cases} D = \sqrt[3]{C \times T} \\ T = aU_1 + bU_2 + \dots + mU_n \end{cases} \tag{9}$$

where D is the coupling coordination degree of the supply-demand-support system of cultural tourism, and T is the comprehensive adjustment index of the supply-demand-support system of cultural tourism, a, b,..... m is the undetermined coefficient of the supply-demand-support system of cultural tourism. According to the development balance between the supply-demand-support system of cultural tourism, the benefits

Table 2 Weights of evaluation factors of tourism supply-demand-support system.

Indicators	Number	Factors	Number	Factors weights	Indicator weights
Supply subsystem B ₁	1	The number of cultural tourism resources	X ₁₁	0.1130	0.0162
	2	Number of natural tourism resources	X ₁₂	0.0966	0.0192
	3	Number of 5A-level tourist attractions	X ₂₁	0.1197	0.0164
	4	Number of star-rated tourist hotels	X ₂₂	0.1042	0.0203
	5	Number of travel agencies	X ₂₃	0.1114	0.0177
	6	Number of performing arts groups	X ₂₄	0.2605	0.0189
	7	Number of museums	X ₂₅	0.1306	0.0442
	8	Number of cultural centers	X ₂₆	0.0641	0.0221
Demand subsystem B ₁	9	The growth rate of domestic tourists	X ₃₁	0.0085	0.0109
	10	The number of inbound tourists	X ₃₂	0.1745	0.0030
	11	The total number of people in circulation of the library	X ₃₃	0.1065	0.0616
	12	Total number of visitors to the museum	X ₃₄	0.0880	0.0376
	13	The number of domestic performance audiences of art performance groups	X ₃₅	0.1365	0.0311
	14	Per capita tourism expenditure of domestic tourists	X ₄₁	0.0461	0.0482
	15	Per capita tourism expenditure of domestic tourists	X ₄₂	0.0654	0.0163
	16	Operating income of cultural market operating institutions	X ₄₃	0.3148	0.0231
Support for subsystems B ₃	17	Information Index	X ₄₄	0.0599	0.1111
	18	Rail density	X ₅₁	0.0373	0.0211
	19	Highway mileage	X ₅₂	0.0339	0.0178
	20	Air transport volume	X ₅₃	0.0860	0.0162
	21	The total volume of postal and telecommunications services	X ₅₄	0.1065	0.0411
	22	Number of toilets per 10,000 people	X ₅₅	0.0196	0.0509
	23	Number of cultural tourism patents	X ₆₁	0.1195	0.0094
	24	Number of students enrolled in the arts and culture category/ Number of students majoring in tourism	X ₆₂	0.0378	0.0571
	25	Cultural and artistic research institutions	X ₆₃	0.0782	0.0181
	26	The amount of investment in cultural undertakings	X ₆₄	0.0524	0.0373
	27	Number of legal entities in the catering industry	X ₇₁	0.0718	0.0250
	28	Average business turnover of accommodation enterprises	X ₇₂	0.0312	0.0343
	29	Distribution density of the retail sector	X ₇₃	0.1576	0.0149
	30	The average turnover of a travel agency	X ₇₄	0.0690	0.0753
	31	The ratio of tourist arrivals to passenger traffic	X ₇₅	0.0772	0.0329
	32	The proportion of total tourism income in the investment in fixed assets of the tertiary industry	X ₇₆	0.0220	0.0369

Calculated according to Publication (1)-(5).

of other subsystems cannot be harmed, so the equal weight of the system is considered, and according to the existing research results, it is considered that the three have an equally important role in the development of the system. Therefore, the undetermined coefficient of the supply-demand-support system of cultural tourism is 1/3.

Referring to the existing relevant studies on tourism and ecology, urbanization (Weng Gangmin et al., 2021), tourism and industrial efficiency (Wang Zhao & Li Tao, 2021), and the coupling relationship between tourism resources and new urbanization (ShaoHaiqin et al., 2021) in the existing research literature, the “0.1 segmentation cut-off method” is used to divide the cultural tourism system into three development stages: coordinated development, transitional development and unbalanced development, and each major category is divided into four specific types: supply lag type, demand lag type, guarantee lag type and supply, demand and support synchronization type. It is divided into three categories: disorders, transitions, and coordination (see Table 3 for details).

Geographically weighted regression model. Geographically weighted regression model (GWR model), is based on the idea of local smoothness (Han Jing et al., 2020), is a regression analysis tool with spatial variable coefficients, which is different from the ordinary linear regression model (OLS) (Sun Cai-zhi et al., 2020). The GTWR model is a method proposed by Huang (2010)

(Huang et al., 2010) on the basis of the GWR model, which can effectively deal with the spatiotemporal nonstationarity by introducing the temporal dimension on the basis of considering space (Wu Xiaoying et al., 2021). Therefore, compared with the GWR model, the proposed model can better describe the spatiotemporal relationship between the explanatory variable and the dependent variable, and the basic expression (Huang et al., 2010) of the GTWR model is:

$$y_i = \beta_0(u_i, v_i, t_i) + \sum_k \beta_k(u_i, v_i, t_i) X_{ik} + \epsilon_i \quad (10)$$

In this study, the longitude and latitude coordinates of the provincial capitals of 31 provinces, autonomous regions and municipalities are used as the calculated latitude and longitude coordinates of the GTWR model, t_i represents the observation time of the sample, y_i represents the value of the dependent variable of the ith sample point, X_{ik} represents the k-th explanatory variable of the ith sample point, ε_i is the error term of the model, β₀(u_i, v_i, t_i) represents the regression constant of the ith sample point, β_k(u_i, v_i, t_i) The regression coefficient representing the k-th explanatory variable of the ith sample point. The specific formula for estimating the regression coefficient is:

$$\hat{\beta}(u_i, v_i, t_i) = [X^T W(u_i, v_i, t_i) X]^{-1} X^T W(u_i, v_i, t_i) Y \quad (11)$$

where: W(ui, vi, ti) represents the weight of the spatiotemporal

Table 3 Stages of development of the cultural tourism supply-demand-support system coupling and coordination.

Stage	Categories		Specific type	
	Divide by	Type	Type	Divide by
Coordinated development	[0.6, 1]	Primary coordination [0.6, 0.7] Intermediate coordination [0.7, 0.8] Good coordination [0.8, 0.9] High-quality coordination [0.9, 1]	Coordinate the development of lagging supply Coordination of development needs lag type Coordinated development supports lagging type Coordinate the development of supply, demand, and support synchronization	$U_2-U_1 \geq 0.1$ or $U_3-U_1 \geq 0.1$; $U_1-U_2 \geq 0.1$ or $U_3-U_2 \geq 0.1$; $U_1-U_3 \geq 0.1$ or $U_2-U_3 \geq 0.1$; U_1, U_2, U_3 , if the difference between any two items is less than 0.1 ;
	[0.4, 0.6]	On the verge of disorder [0.4, 0.5] Barely coordinated [0.5, 0.6]	Transitional development and lagging supply Transitional development needs to lag behind Transitional development support lags behind Transitional development of supply, demand, and support synchronization	$U_2-U_1 \geq 0.1$ or $U_3-U_1 \geq 0.1$; $U_1-U_2 \geq 0.1$ or $U_3-U_2 \geq 0.1$; $U_1-U_3 \geq 0.1$ or $U_2-U_3 \geq 0.1$; U_1, U_2, U_3 , if the difference between any two items is less than 0.1 ;
	[0.0, 0.4]	Extreme dysregulation [0.0, 0.1] Severe dysregulation [0.1, 0.2] Moderate disorder [0.2, 0.3] Mild disorder [0.3, 0.4]	Dysfunctional development and lagging supply Dysfunctional development needs lag type Dysfunctional development, support lag type Abnormal development of supply, demand, and support synchronization	$U_2-U_1 \geq 0.1$ or $U_3-U_1 \geq 0.1$; $U_1-U_2 \geq 0.1$ or $U_3-U_2 \geq 0.1$; $U_1-U_3 \geq 0.1$ or $U_2-U_3 \geq 0.1$; U_1, U_2, U_3 , if the difference between any two items is less than 0.1 ;

position i , and the spatiotemporal weight matrix of the GTWR model is constructed to determine the influence of the values of other sample points on the regression sample points, so the spatiotemporal weight matrix plays a core role in the calculation process of the GTWR model, and this form forms a diagonal matrix, which is expressed as $W(u_i, v_i, t_i) = \text{diag}(\alpha_{i1}, \alpha_{i2}, \dots, \alpha_{in})$. The process of constructing the spatiotemporal distance weight matrix $W(u_i, v_i, t_i)$ is as follows:

Firstly, the Euclidean distance is used to calculate the spatial distance between sample points, and in the same way, the temporal distance between samples is calculated. The calculation of space-time distance is mainly as follows:

$$(d^{ST})^2 = \lambda(d^S)^2 + \mu(d^T)^2 \tag{12}$$

Then, the weight matrix is calculated, that is, the weight function generally chooses the Gaussian function or the bi-square function, which can be converted into the weight function after being brought in, and the weight matrix is calculated, and the specific formula is as follows:

$$W_{ij} = \exp \left\{ - \frac{\left[\left(u_i - u_j \right)^2 + \left(v_i - v_j \right)^2 \right] + \tau \left(t_i - t_j \right)^2}{\left(h_s \right)^2} \right\} \tag{13}$$

There is an obvious spatial correlation between the coupling and coordination level of supply, demand, and support of cultural tourism in China, which cannot meet the classical assumption that the variables are independent of each other in the traditional econometric model, which will lead to the bias of OLS estimation results (Wang Zhaofeng & Xie Jialiang, 2023), while the GTWR model considering spatiotemporal nonstationarity is more reasonable and effective. In order to evaluate the rationality of model selection, the GTWR model was comprehensively judged with the help of criteria such as Akaike Information Criterion (AICc), Sum of Squares of Residuals (RSS), and Adjusted Goodness-of-Fit (R2Adj) (Wang Zhaofeng & Xie Jialiang, 2023). Based on the existing research, this study uses the GTWR model to analyze the spatiotemporal variation characteristics of the coupling coordination factors of tourism supply, demand and support.

Analysis of results

Analysis of the coupling and coordination stage of the national tourism supply-demand-support system. According to the entropy method, the comprehensive evaluation value of the 32 index systems of the cultural tourism supply-demand-support system was calculated (6-9), and the coupling coordination degree of the cultural tourism supply-demand-support system in the whole country and the seven regions of the east and northeast China from 2007 to 2020 was calculated through the coupling coordination degree model of the cultural tourism system, which was divided into major types of imbalanced, transitional and coordinated development and different specific types (see Table 4 for details).

On the whole, the supply, demand and support system of cultural tourism have a high degree of correlation, and the level of coupling and coordination shows an upward trend, from high coupling and low coordination to high coupling and high coordination, showing a good development trend, and the coupling degree of the three remains above 0.9 except in 2008. The supply, demand and support system of cultural tourism has a strong ability to develop in a coordinated manner, that is, the coupling and coordination have developed from 0.1126 in 2007 to 0.8928 in 2020, with an average value of 0.5882 and an average

Table 4 Coupling coordination degree and type of cultural tourism in China from 2007 to 2020.

Year	C	D	Type
2007	0.9420	0.1126	Severe imbalance in supply, demand, and support synchronization
2008	0.6949	0.1766	Severe imbalance of demand lag type
2009	0.9212	0.2993	Moderate imbalance in supply, demand, and support synchronization
2010	0.9915	0.3627	Mild imbalance of supply, demand, and support synchronization
2011	0.9816	0.4431	On the verge of imbalance supply, demand, and support synchronization
2012	0.9718	0.5145	Barely coordinated support lag type
2013	0.9696	0.5914	Barely coordinate demand, support lag type
2014	0.9716	0.6196	Primary coordination demand, support lag type
2015	0.9837	0.6965	Primary coordination support lag type
2016	0.9901	0.7628	Intermediate coordination support lag type
2017	0.9875	0.8683	Good coordination of supply, support lag type
2018	0.9990	0.9079	High-quality coordination of supply, demand, and support synchronization
2019	0.9997	0.9865	High-quality coordinated supply lag type
2020	0.9871	0.8928	Well-coordinated demand lag type

"C" is the coupling degree of the supply-demand-support subsystem of cultural tourism; "D" is the coupling coordination degree of the supply-demand-support subsystem of cultural tourism.

annual growth rate of 17.27%. From 2007 to 2020, the development stage of the supply-demand-support system of cultural tourism can be divided into the stage of disorder development (2007–2010), the stage of transitional development (2011–2013), and the stage of coordinated development (2014–2020) (see Table 4 for details). Specifically:

Stages of disorder development. From 2007 to 2010, the coupling degree increased from 0.9420 in 2007 to 0.9915 in 2010, an increase of 5.25%, with an average annual growth of 1.72%, while the coupling coordination degree increased from 0.1126 in 2007 to 0.3627 in 2010, an increase of 222.11% and an average annual growth of 47.68%, indicating that there is a strong relationship between the supply-demand-support system of cultural tourism. It maintains a relatively stable development relationship, but its coupling and coordination are relatively poor in development ability; there is an obvious growth trend. From 2007 to 2010, except for 2008, when demand lagged behind, the rest of the years were synchronous in supply, demand and support, which were mainly divided into three different types: severe imbalance, moderate imbalance and mild imbalance. In 2008, the supply-demand-support system of cultural tourism showed the characteristics of lagging demand, which had a lot to do with the occurrence of the financial crisis in 2008. In 2007, China began the evaluation of national 5A-level tourist attractions. From the perspective of the supporting subsystem of China's cultural tourism, because the product supply of cultural tourism is mainly a relatively independent system, the layout of its infrastructure and service facilities presents the construction of supporting subsystems around scenic spots, museums and other areas, and the supporting facilities and service facilities around other non-tourist attractions are relatively weak.

Transitional development stage. From 2011 to 2013, the stage of transition and development was the stage of transition, and the coupling degree decreased, but the coupling and coordination ability continued to improve, and the product supply capacity of cultural tourism continued to mature, but the market demand and support system were relatively weak, which were on the verge of imbalance in the supply, demand, and support synchronization type, and the barely coordinated support lag type and the barely coordinated demand and support lag type. The coupling degree increased from 0.9816 in 2011 to 0.9696 in 2013, a decrease of 1.22%, with an average annual decrease of 0.61%, while the coupling coordination degree increased from 0.4431 in 2011 to 0.5914 in 2013, an increase of 33.47%, and an average annual

growth of 15.53%, indicating that there is a strong relationship between the supply-demand-support system of cultural tourism, and its coordination has also shown a good development trend, and the comprehensive development ability of the three is characterized by relatively balanced development. In 2013, the number of domestic tourists was 3.262 billion, and the income was 2,627.612 billion yuan, an increase of 10.3% and 15.7% respectively over the previous year, and the number of inbound tourists was 129 million, and the national tourism foreign exchange income was 51.664 billion US dollars, showing a prosperous development trend, and under the development of this trend, the product supply of the cultural tourism system put forward new challenges and opportunities. The traditional sightseeing cultural tourism market is no longer satisfied with the needs of the existing consumer market, but the demand for cultural, experiential and personalized cultural tourism products is gradually increasing. The market demand capacity has also been greatly improved, and the traditional cultural tourism product system has been unable to meet the existing market demand, which has posed new challenges to the supply capacity of cultural tourism products.

Coordinated development stage. From 2014 to 2020, the coupling degree increased from 0.9716 in 2014 to 0.9871 in 2020, an increase of 1.60%, with an average annual growth of 0.26%, and the coupling coordination degree increased from 0.6196 in 2014 to 0.8928 in 2020, an increase of 44.09%, with an average annual growth of 6.28%, indicating that there is a strong relationship between the supply-demand-support system of cultural tourism. Its coordination has changed to more high-quality characteristics, and the increase has been significantly improved. At this stage, new formats and product systems have been continuously cultivated, focusing on the application of science and technology and the cultivation of digital products. A diversified, fashionable and networked product system has emerged, and the core competitiveness of cultural tourism has been continuously enhanced. As a result, the connotative growth and self-cultivation ability of cultural tourism supply capacity are lacking, and the continuous improvement of its support capacity has not formed a good coupling relationship.

Analysis of the development stages of regional coupling and coordination. From the perspective of the development trend of regional coupling and coordination, the supply-demand-support system of cultural tourism in seven regions including Northeast

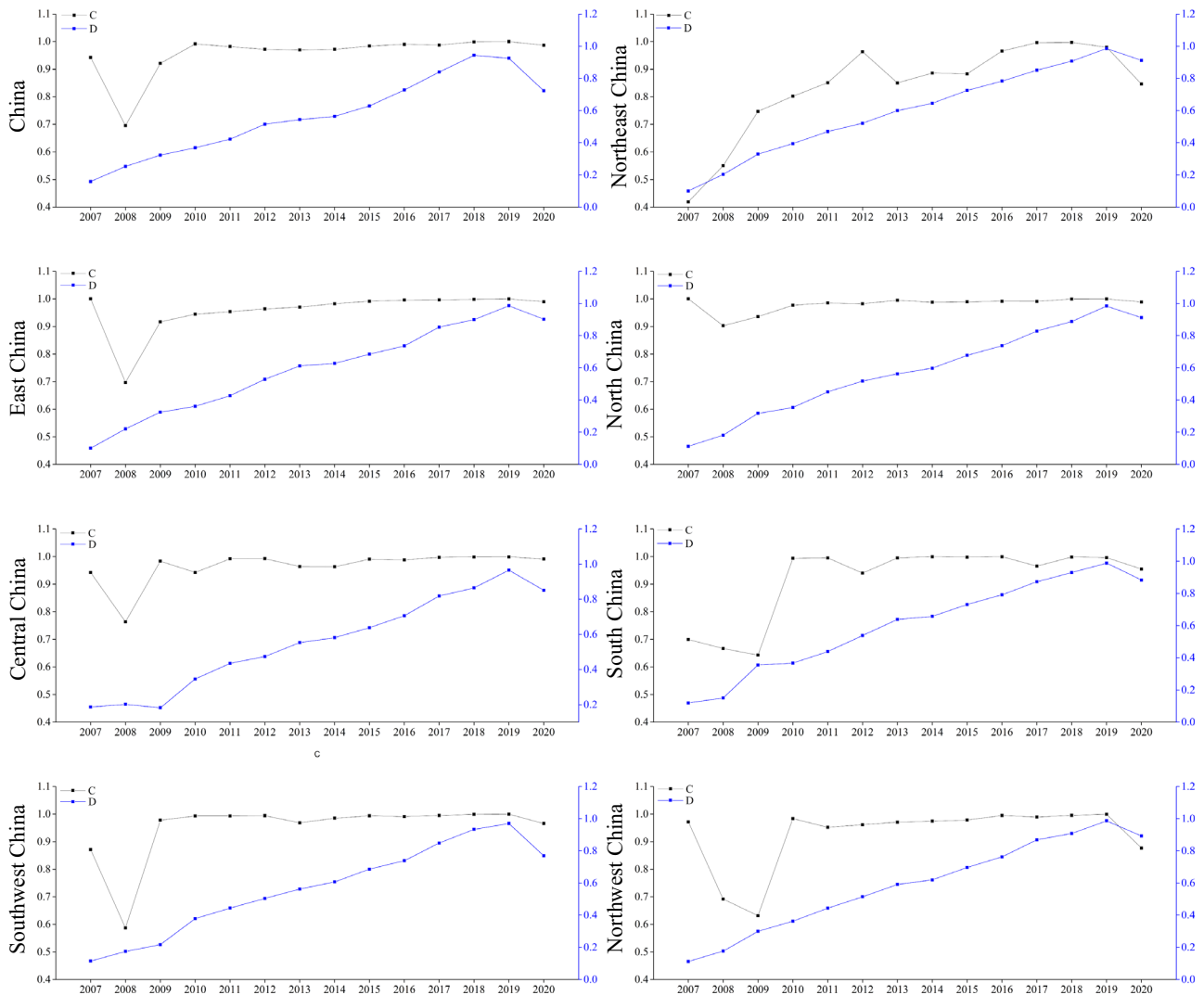


Fig. 2 Line chart of the coupling and coordination relationship between the supply-demand-support system of cultural tourism from 2007 to 2020.

China has a high degree of relevance, and its coupling and coordinated development ability continues to improve, and East China, North China, Central China, Southwest China, Northwest China, and Northeast China show an obvious trend from high coupling and low coordination to high coupling and high coordination, while South China has a trend of transformation from low coupling and low coordination to high coupling and high coordination. Specifically:

Firstly, the three regions of Northeast China, Central China, and Southwest China have changed from high coupling and low coordination to high coupling and high coordination, and the growth rate of the coupling coordination degree is significantly faster than the growth rate of the coupling degree. First, the coupling degree in Northeast China increased from 0.4191 in 2007 to 0.8457 in 2020, with an average value of 0.8382, an increase of 101.82% and an average annual growth rate of 5.55%; The coupling coordination degree increased from 0.1588 in 2007 to 0.7299 in 2020, with an average value of 0.5666, an increase of 355.12% and an average annual growth of 12.36%. Second, the coupling degree in Central China increased from 0.9426 in 2007 to 0.9910 in 2020, with an average value of 0.9650, an increase of 5.14%, and an average annual increase of 0.39%. The coupling coordination degree increased from 0.1125 in 2007 to 0.9119 in 2020, with an average value of 0.5800, an increase of 710.41% and an average annual growth of 17.46%. Thirdly, the coupling degree

in South China increased from 0.6995 in 2007 to 0.9551 in 2020, with an average value of 0.9177, an increase of 36.54% and an average annual increase of 2.42%. The coupling coordination degree increased from 0.1863 in 2007 to 0.8510 in 2020, with an average value of 0.5573, an increase of 356.82% and an average annual growth of 12.40% (Fig. 2).

Secondly, the southwest region has changed from high coupling and low coordination to high coupling and high coordination, and the growth rate of the coupling coordination degree is significantly faster than the growth rate of the coupling degree. That is, the coupling degree increased from 0.8710 in 2007 to 0.9658 in 2020, with an average value of 0.9510, an increase of 10.89%, and an average annual increase of 0.80%. The coupling coordination degree increased from 0.1196 in 2007 to 0.8838 in 2020, with an average value of 0.6043, an increase of 638.93% and an average annual growth of 16.63% (Fig. 2).

Thirdly, East China, North China and Northwest China have changed from high coupling and low coordination to high coupling and high coordination, and the coupling degree has decreased, but the coupling coordination degree has shown a significant growth trend. First, the coupling degree in East China decreased from 1.000 in 2007 to 0.9894 in 2020, with an average value of 0.9570, a decrease of 1.06%, and an average annual decrease of 0.08%; The coupling coordination degree increased from 0.1000 in 2007 to 0.9113 in 2020, with an average value of

Table 5 Influencing factors of cultural tourism supply-demand-support system.

Number	Influencing factors	Indicator selection	Unit	Data source
X1	Degree of openness	The value of imports and exports of goods as a proportion of regional GDP	%	China Statistical Yearbook
X2	Technological development	Science and technology costs	Billion dollars	China Statistical Yearbook
X3	Potential consumption	Per capita consumption expenditure on education, culture and entertainment	Dollar	China Social Statistical Yearbook
X4	Residents' consumption	Engel's coefficient	%	China Statistical Yearbook
X5	Industry support	The tertiary sector accounts for a proportion of GDP	%	China Statistical Yearbook
X6	Financial security	GDP growth rate	%	China Statistical Yearbook

Table 6 Variable description.

Variable	Obs	Mean	Std. dev.	Min	Max	S-W test	K-S test
Y	434	0.328	0.011	0.113	0.625	0.981 (0.000***)	0.062 (0.068*)
X1	434	33.244	1613.336	4.081	171.09	0.692 (0.000***)	0.264 (0.000***)
X2	434	36.676	3297.819	0.203	344.938	0.625 (0.000***)	0.263 (0.000***)
X3	434	52.164	1061.496	7.435	189.46	0.924 (0.000***)	0.126 (0.000***)
X4	434	36.717	19.17	23.75	51.213	0.979 (0.000***)	0.076 (0.013**)
X5	434	40.371	63.439	28.6	77.9	0.788 (0.000***)	0.194 (0.000***)
X6	434	9.162	11.437	-5.4	18	0.990 (0.007***)	0.042 (0.414)

***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.

0.6016, an increase of 811.34% and an average annual growth of 18.35%. The coupling degree in North China decreased from 1.000 in 2007 to 0.9885 in 2020, with an average value of 0.9803, a decrease of 1.15%, and an average annual decrease of 0.09%. The coupling coordination degree increased from 0.1000 in 2007 to 0.9018 in 2020, with an average value of 0.5902, an increase of 801.83% and an average annual growth of 18.43%. Thirdly, the coupling degree in Northwest China increased from 0.9720 in 2007 to 0.8768 in 2020, with an average value of 0.9266, a decrease of 9.80% and an average annual decrease of 0.79%. The coupling coordination degree increased from 0.1142 in 2007 to 0.7691 in 2020, with an average value of 0.5678, an increase of 573.39% and an average annual growth of 15.80% (Fig. 2).

“C” is the coupling degree of the supply-demand-support system of cultural tourism;

“D” is the coupling coordination degree of the supply-demand-support subsystem of cultural tourism.

Analysis of influencing factors. The GTWR model (10-13) is used to analyze and explore the influencing factors of the coupling and coordinated development of the supply-demand-support system of cultural tourism, and the influence degree and spatiotemporal characteristics of the influencing factors are analyzed.

Select influencing factors. On the basis of existing research, focusing on the consideration of the influencing factors of innovation in the development of cultural tourism system, the proportion of import and export of goods in regional GDP (Lei Hongzhen & Li Yun, 2020), science and technology expenditure (Wu Xiaoying et al., 2021), per capita consumption expenditure of residents in education, culture and entertainment, Engel coefficient (Huang Changyong & Xie Xuefang, 2017), and the proportion of tertiary industry in GDP (Hu Chu-chu & Zhou Zhi-xiang, 2018) (Table 5) evaluation factors were selected to measure the level of openness, scientific and technological development, potential consumption, residents' consumption capacity, industrial support capacity, and the degree of openness, scientific and technological development, potential consumption,

residents' consumption capacity, and industrial support capacity that affect the coupling and coordinated development of the system. economic security capacity, explore the influencing factors of high-quality development of cultural tourism transformation, and then put forward targeted countermeasures and suggestions.

The Tobit regression model is used to calculate the value of the coupling coordination degree, which is mainly analyzed with the analysis results of the GTWR model. Before the regression analysis, the stationarity test of the data showed significant stationarity within the 95% confidence interval and the first-order difference of Y, X1 ~ X6 (see Table 6 and 7 for details), and then the results of the Kendall coefficient consistency test for each index showed that The significance P-value of the overall data is 0.000, which is horizontally significant, rejecting the null hypothesis, so the data is consistent, and the Kendall coordination coefficient W value of the model is 0.748, so the degree of correlation is highly consistent, indicating that regression analysis can be performed (Tables 6 and 7).

As can be seen from Table 8, the R2 (0.8772) of the GTWR model is significantly better than that of the OLS model (0.5407), and the sum of squares of the Akaike information criterion and residuals is also lower than that of the OLS model, which fully confirms that the GTWR model is more reasonable and effective [30], the GTWR model with better R2 is used for further explanation and calculation. However, considering the spatio-temporal variation characteristics of the national cultural tourism supply-demand-support system from 2007 to 2020. According to the Geoda statistical analysis software, the Moran's I index of the coupling coordination degree of the supply demand and support system of the national cultural tourism from 2007 to 2020 is greater than 0 and less than 0.5, the P value is less than 0.05 (through the 95% confidence test), and the Z-score is more than the critical value of 1.65, indicating that the supply demand and support system of cultural tourism. The coupling and coordinated development level of various elements shows the characteristics of spatial positive correlation over a long period of time, and there is potential spatial interdependence in a certain geographical range.

Table 7 Unit root test results of influencing factors.

Variable	Test results	
	t-value	P-value
Y	1.007	0.000***
X1	3.993	0.000***
X2	3.733	0.000***
X3	5.712	0.000***
X4	5.262	0.000***
X5	5.568	0.000***
X6	2.747	0.000***

***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively

Table 8 Unit root test results of influencing factors.

Variable	GTWR	OLS
X ₁	-	0.00104***
X ₂	-	0.00151***
X ₃	-	0.00056***
X ₄	-	-0.00001***
X ₅	-	-0.00698***
X ₆	-	-0.000367***
R ²	0.8772	0.5407
RSS	0.3899	1.4505
AICc	-466.808	-360.9731

***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.

Analysis of calculation results. In general, after analyzing the temporal and spatial variation characteristics of the influencing factors using the GTWR model, and visualizing the regression coefficients, it is found that the degree of openness changes from the trend of south to north to the southwest, northeast, Xinjiang, Qinghai and other provinces and regions, and the effect of Yunnan and other provinces and regions changes from positive to negative. The influence of scientific and technological development has continuously improved, showing a trend of change from west to east, and the scope of influence of potential consumption has gradually expanded, from southwest and east China to Tibet, Jiangxi and other provinces and regions, as well as central and eastern China. The influencing capacity of the high-value areas of household consumption has been continuously enhanced, showing a decreasing trend from the east and west to the middle, and the influencing capacity of industrial support has continued to expand, gradually concentrated in the northeast and northwest regions, as well as Beijing, Tianjin and other provinces and regions, showing a decreasing trend from the northeast and northwest to other regions. The economic security capacity has also been continuously improved, gradually concentrated in the eastern region and some provinces and regions such as Xinjiang and Tibet, showing a decreasing trend from the east and west to the central region. Specifically:

(1) Analysis of the impact of openness on the supply, demand and support system of cultural tourism. In 2007, the areas with high regression coefficients of openness were mainly distributed in East China, Central China, Southwest China, and Northeast China (Fig. 3a), showing a decreasing trend from south to north, and although the number of areas with positive regression coefficients decreased by 2020 (Fig. 3g), not only in the regions with high economic level, but also in the economically weak regions of Northwest China such as Xinjiang and Qinghai, showing a diffusion from the southwest, northeast China, and

some provinces and regions such as Xinjiang and Qinghai. During the period of 2007-2020, the influence area of the degree of opening up to the outside world on the cultural tourism system has been continuously broadened, and some continuous attention needs to be paid to its development and influence. The reason is that Guangdong, Hainan, Guangxi and other economically developed regions can provide more suitable development conditions for the development of the level of opening up, can provide a more open external environment for the development of cultural tourism, and is easy to attract more foreign tourists to participate and experience, so that the moderate degree of openness can provide more high-quality public service system, transportation service system, basic service facilities and other service facilities such as catering for the development of cultural tourism, and form a benign interaction between the destination and the source of tourists. In turn, it will inject new driving force into the supply of cultural tourism products and promote the sustainable development of cultural tourism. Xinjiang, Qinghai and other regions with weak economic development levels have a high degree of dependence on foreign countries due to their weak development capabilities, especially the development of cultural tourism, which needs the support of external tourist sources to help the development of cultural tourism. Heilongjiang and other Northeast regions have gradually increased their own development capacity, while the development of openness has decreased the impact of the development ability of the coupling and coordination of the cultural tourism supply-demand-support system. It should be noted that the influence of the degree of openness in Yunnan, Sichuan, Shaanxi, Anhui, Hubei, Zhejiang, Jiangsu and other provinces and regions has turned from positive to negative, indicating that the degree of excessive openness to the outside world will lead to the outflow of tourists, so that the local cultural tourism resources can not be fully utilized, thus producing a certain degree of negative effect. As an important area for the development of border tourism, Yunnan's tourism industry is an inevitable requirement for the sustainable, healthy and rapid development of the tourism industry. In the process of regional sustainable development, it is necessary to give full play to the powerful radiation function of the tourism industry and integrate it into the diversified cooperation of transportation, finance, catering, accommodation, logistics, commerce and trade, so as to help the high-quality development of the regional economy (Ming Qingzhong & Zhou Yulin, 2019).

(2) Analysis of the impact of scientific and technological development on the supply, demand and support system of cultural tourism. In 2007, the positive regression coefficient of science and technology development was mainly distributed in the northwest and southwest (Fig. 3b), showing a decreasing trend from west to east, and by 2020, although the number of areas with positive regression coefficient of science and technology development increased, the development trend remained basically unchanged (Fig. 3h). From 2007 to 2020, the influence of scientific and technological development on the supply and demand support system of cultural tourism remains basically unchanged, which is a relatively stable factor for the sustainable development of this system, and it still needs to be systematically maintained. The reason is that economically developed regions such as Sichuan Province can provide more convenient scientific research support conditions for the development of science and technology, and moderate scientific and technological development can provide a strong driving capacity for the development of cultural tourism, forming a benign interaction between product supply and market. Qinghai, Gansu, Ningxia, Tibet and other regions with weak economic development level, because of their own development ability is not strong, the existing scientific and technological development has become

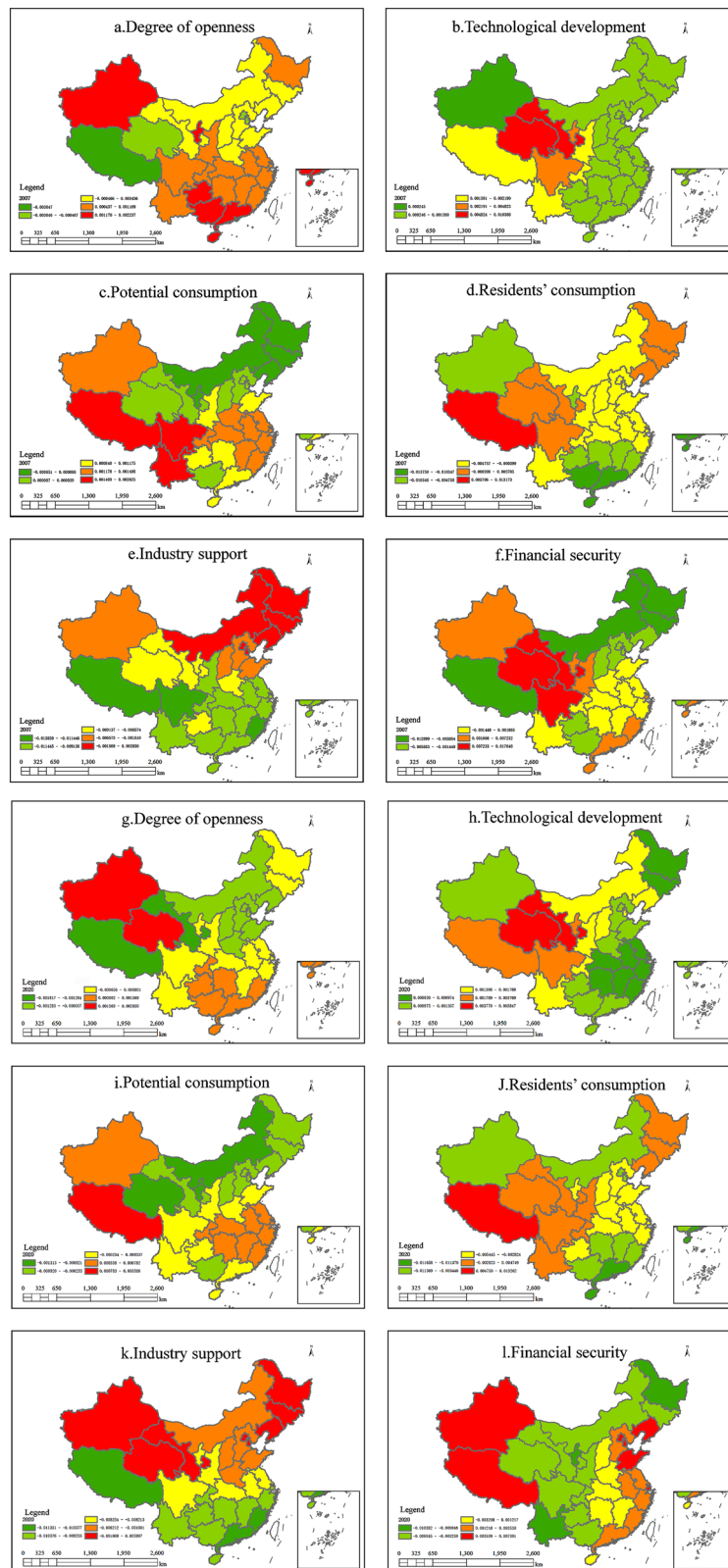


Fig. 3 The spatiotemporal pattern of the influencing factors of the coupling and coordinated development of the cultural tourism supply[1]demand-support system from 2007 to 2020. Note: **a, b, c, d, e,** and **f** represent the degree of openness, Technological development, Potential consumption, Residents' consumption, Industry support, Financial security of the coupling and coordination factors of China 's cultural tourism supply and demand support system in 2007. **g, h, i, j, k,** and **l** represent the degree of openness, Technological development, Potential consumption, Residents' consumption, Industry support, Financial security of the coupling and coordination factors of China 's cultural tourism supply and demand support system in 2020.

the key support for the development of its cultural tourism at a higher level, on the one hand, the development of science and technology can achieve a diversified and personalized supply system for the supply of cultural tourism products, can provide a unique product system for market demand, and become an important support for the coupling and coordinated development of cultural tourism; On the other hand, the development of science and technology can also provide technical support for the development of destinations with strong specialization of special products such as eco-tourism, ethnic tourism, leisure tourism, and cultural tourism, and effectively ensure the effective conversion between cultural tourism resources and product supply. In particular, the development of cultural tourism needs the support of scientific and technological development according to local conditions, and comprehensively helps the scientific and technological development of cultural tourism. The influence of scientific and technological development capacity on the coupling and coordinated development ability of the cultural tourism supply-demand-support system in the eastern region has decreased. It should be noted that the impact of scientific and technological development is positive, indicating that scientific and technological development provides more effective support for the comprehensive development of cultural tourism, and realizes the rational and scientific transformation of local cultural tourism resources into products. There is a long-term interactive response relationship between digital inclusive finance and the efficiency of the tourism industry. The efficiency of the tourism industry has the first and later lasting effects on the process of digital inclusive finance. The impact of digital inclusive finance on the efficiency of the tourism industry is instant and continuous (Guo Xiangyang & Ming Qingzhong, 2025). In the process of scientific and technological development, we need to pay attention to the important role of digital cultural tourism in the development of the supply and demand support system, and improve the sustainable power of cultural tourism development. In the process of sustainable development of cultural tourism, it is still necessary to pay attention to the content output brought by live tourism and the influence mechanism on the field willingness of cultural tourism consumers. This research process requires an effective interaction between the richness of live broadcast information and the willingness of tourist destinations (Wang Yuchen et al., 2024), and then brings new vitality to the sustainable development of tourism through 'tourism + live broadcast' to achieve its sustainable development (He Chang et al., 2023).

(3) Analysis of the impact of potential consumption on the supply, demand and support system of cultural tourism. In 2007, the positive potential consumption regression coefficient areas were mainly distributed in southwest and east China (Fig. 3c), showing a decreasing trend from the Yangtze River basin and Tibet and other provinces to the north and south, and by 2020, although the number of areas with positive potential consumption coefficients decreased, mainly from Tibet, Jiangxi and other provinces and regions and Central and East China to the surrounding areas, showing a certain circle change trend (Fig. 3i). From 2007 to 2020, the impact of potential consumption on the supply, demand and support system of cultural tourism has changed greatly. It is not only the eastern developed areas that have a greater impact on it, but also the potential of the western and eastern regions on it continues to expand. The reason is that the income of residents in economically developed regions such as Central China and East China is higher, and the consumption expenditure on education, culture and entertainment is higher than that of areas with weak economic development, which can provide large-scale personnel for the consumption of cultural tourism products, maximize the labor value of cultural tourism

product producers, drive producers to produce more attractive cultural tourism products, and continuously inject impetus and support for the development of cultural tourism. Tibet and other regions with a weak economic development level are not strong in their own development capabilities, so the smaller expenditure on education, culture and entertainment is precious, and the role in the consumption process of the cultural tourism market is more prominent, becoming an important market driving factor for the coupling and coordinated development of cultural tourism. In particular, the development of cultural tourism needs the support of scientific and technological development according to local conditions, and comprehensively helps the scientific and technological development of cultural tourism. It should be noted that the negative impact of potential consumption is obvious, and the impact effect of potential consumption in Gansu, Shaanxi, Heilongjiang and other provinces and regions has turned from positive to negative, indicating that excessive potential consumption will lead to the continuous expansion of the scale of consumption, but the supply of products can not meet the demand for more high-quality products, restricting the benign transformation between products and markets, and making the products of cultural tourism development appear slightly insufficient, thus producing a certain degree of negative effect. The mismatch between supply and demand structure is an important reason for the sluggish consumption of residents and the obstruction of internal circulation (Yang Jisheng & Li Jiaolong, 2024). Similarly, in the process of supplying cultural tourism products, it is necessary to consider the consumption demand of residents, improve the spatial effective way of long-term growth of the cultural tourism economy, and achieve the goal of sustainable development of cultural tourism.

(4) Analysis of the impact of residents' consumption on the supply, demand and support system of cultural tourism. In 2007, the high-value areas of the regression coefficient of household consumption were mainly distributed in Tibet (Fig. 3d), showing a decreasing trend from the east and west sides to the middle, and the number of high-value areas of the regression coefficient of residents increased by 2020, and the spatial trend remained basically unchanged from that in 2007 (Fig. 3j). From 2007 to 2020, the influence of residents' consumption on the supply and demand of cultural tourism and the supporting system has maintained a relatively stable development trend, but the influence of residents' consumption in Tibet and other regions has shown a rapid growth trend. The reason is that the income of residents in Tibet and other areas with low economic development is low, so the consumption in daily life is mainly concentrated in material consumption, while the expenditure on spiritual consumption is low, especially for the development of cultural tourism, which is a necessity for people's spiritual life, and residents need to invest more support in spiritual life consumption, which has an obvious negative correlation with the level of economic development. In Guangdong, Beijing, Shanghai and other regions with a strong level of economic development, the stronger the residents' consumption capacity, the lower the Engel coefficient, the content of material demand in the overall consumption process is insufficient, and more attention is paid to spiritual life, which requires cultural tourism and other spiritual life products to be provided. Especially in the process of cultural tourism becoming more and more a necessity of life, it is more necessary to support residents' consumption according to local conditions. The phenomenon of "resource curse" is a new problem accompanied by the development of energy resources (Chen Zuhai et al., 2015). Its transmission mechanism also affects residents' consumption through a gradual increase. When cultural tourism has gradually become a hot spot of consumption, how to better solve the phenomenon of "resource curse" through

cultural tourism consumption has become a key problem to be solved in the sustainable development of the regional economy and society. Especially in the development process of cultural tourism, resources are the key support for the high-quality development of a regional cultural tourism product, which can be solved through the consumer-oriented product transmission mechanism.

(5) Analysis of the impact of industrial support on the supply, demand and support system of cultural tourism. In 2007, the high-value areas of industrial support regression coefficient were mainly distributed in Northeast China and Inner Mongolia, Beijing, Tianjin and other provinces and regions (Fig. 3e), showing a decreasing trend from northeast to southwest, and by 2020, the number of high-value areas of industrial support coefficient remained increasing, mainly concentrated in northeast and northwest regions, as well as Beijing, Tianjin and other provinces and regions, showing a decreasing trend from northeast and northwest to other regions (Fig. 3k). From 2007 to 2020, the impact of industrial support on the supply, demand and support system of cultural tourism has changed greatly, especially in the northwest and northeast of China, while other regions have maintained a relatively stable support relationship. The reason is that in Beijing, Tianjin and Northeast China, the development level of the tertiary industry has a strong overall role in promoting the development of cultural tourism, and constantly promotes the transformation and upgrading of national economic and social development, which is conducive to the sustainable development of cultural tourism. Xinjiang, Qinghai, Gansu and other regions with weak economic development level, the development of the tertiary industry is more important, especially cultural tourism as a comprehensive industry has an important role in the development of the region, and constantly improve the external cultural self-confidence, enhance the self-confidence of their own development ability, development can become an important means to promote the economy and society. The adjustment of industrial structure, especially with its high-quality development as the goal, needs to play an important role in the innovation-driven factor allocation, the structural optimization of digital technology, the production synergy of institutional change, and the green development effect of spatial agglomeration (Xu Zheng & Jiang Xiaopeng, 2024), so as to promote the high-quality and sustainable development of the tourism industry.

(6) Analysis of the impact of economic security on the supply, demand and support system of cultural tourism. In 2007, the high-value areas of the regression coefficient of economic security were mainly distributed in Northwest China and some provinces and regions such as Sichuan, Hainan, Guangzhou, Shanghai, and Fujian (Fig. 3f), showing a decreasing trend from the northwest and southeast to the surrounding regions, and by 2020, the number of high-value areas with industrial support coefficients remained increasing, mainly concentrated in the eastern region and some provinces and regions such as Xinjiang and Tibet, showing a decreasing trend from the east and west to the central region (Fig. 3l). From 2007 to 2020, the impact of regional economy on the supply, demand and support system of cultural tourism has maintained a relatively stable trend, but the impact of regional economy in Xinjiang, Tibet, Shandong, Liaoning and other provinces on this system has changed more obviously. The reason is that in Shandong, Liaoning, Beijing, Tianjin and other regions with high economic development, cultural tourism, as an important part of industrial development, is affected by the overall economic and social development, and also shows a good development trend. On the contrary, Xinjiang and Tibet and other regions with weak economic development levels have shown great importance in recent years in terms of their economic development capacity, especially the increasingly

prominent role of cultural tourism in their economic and social development. It should be noted that Gansu, Qinghai, Ningxia and other provinces and regions have changed from positive effects to negative effects, indicating that the overall development of the economy and the development of cultural tourism have not formed a consistent pace, and the consistent development of the economy and society has become the focus of the overall development of the region. In this process of change and development, it is necessary to pay attention to the promotion of experiential cultural tourism consumption, narrative cultural communication and social co-creation practice in the production process of cultural tourism products by cultural conformity and cultural communication (Yin Jian & Qin Zongcai, 2024), so as to inject new impetus into the supply and demand support system of cultural tourism.

(1) The spatiotemporal pattern of the influencing factors of the coupling and coordinated development of the cultural tourism supply-demand-support system in 2007.

(2) The spatiotemporal pattern of the influencing factors of the coupling and coordinated development of the cultural tourism supply-demand-support system in 2020.

The map is based on the standard map with the review number GS (2020) No. 4632 downloaded from the standard map service website of the National Administration of Surveying, Mapping and Geoinformation, and the base map has not been modified.

Discussion

On the basis of constructing the theoretical system and evaluation index system of the supply and demand and support system of cultural tourism, this paper studies the spatial and temporal characteristics of the coupling and coordination of the supply and demand and support system of cultural tourism in China from 2007 to 2020 and its influencing factors, and puts forward the countermeasures for the sustainable development of cultural tourism. It not only needs to pay attention to the sustainable development of cultural tourism, but also needs to pay more attention to the path of effective transformation between ecological resources and cultural tourism products (Zeng et al., 2021), so as to provide a typical case study for the sustainable development of cultural tourism supply and demand and support system based on regional ecological resources. The efficiency of culture and tourism industries showed a fluctuating upward trend from 2011 to 2019, but then declined, forming the spatial pattern of the eastern leading and the central convex, respectively (Xie Jialiang & Wang Zhaofeng, 2025). Internationally, such as Japan's cultural tourism industry has also shown a trend of rapid growth, but the characteristics of unbalanced development are more obvious (Liu et al., n.d.). It can be seen that the sustainable development of cultural tourism plays an important role in regional economic and social development.

The national cultural tourism supply-demand-support system can be divided into three stages: the imbalanced development stage (2007–2010), the transitional development stage (2011–2013) and the coordinated development stage (2014–2020). The supply-demand-support system of cultural tourism in South China shows stable coupling development and high-level coupling and coordinated development.

The supply-demand-support system of cultural tourism in seven regions, including Northeast China, has a high degree of relevance, and its coupling and coordinated development ability continues to improve, showing an obvious trend from high coupling and low coordination to high coupling and high coordination, while South China has changed from low coupling and low coordination to high coupling and high coordination. The dysfunctional development stage shows the characteristics of high coupling and low

coordination, and the development rate of coupling coordination is much higher than that of coupling. In the transitional development stage, the development rate of coupling coordination is much higher than that of coupling development, and the coupling development has a certain downward trend. The coordinated development stage shows the characteristics of high coupling and high coordination, and the development speed of coupling and coordination is much higher than that of coupling. This shows a spatial distribution pattern of 'high in the southeast and low in the northwest' with the high-quality integration and development of Chinese culture and tourism. The types of high adaptation-high matching are mainly concentrated in East China, while the types of low adaptation-low matching are mostly distributed in Southwest China, South China and Northeast China (Xie Chaowu et al., 2025). It can be seen that the spatial coupling characteristics of the supply, demand, and support of the subsystem of Chinese cultural tourism show the characteristics of high demand in the southeast and northwest.

The GTWR model is used to analyze the influence of influencing factors based on innovation perspectives, such as openness, scientific and technological development, potential consumption, resident consumption, industrial support, and economic security, on the coupling and coordinated development ability of the cultural tourism supply-demand-support system. The degree of openness greatly affects the ability to change, while the development of the other five influencing factors, such as the development of science and technology, maintains a relatively stable ability. The trend of the influencing factors of openness changed greatly, and the positive area of the transitional development stage remained basically stable, while the positive area of the two stages of imbalanced development and coordinated development decreased. The influencing capacity of scientific and technological development has basically remained stable, showing a steady trend of strengthening, and the characteristics of transitional and coordinated development have remained unchanged except for the decline in the stage of disorderly development. The influencing capacity of potential consumption has remained basically stable, and the characteristics of transitional and coordinated development have remained unchanged, except for the decline in the stage of imbalanced development. The influencing capacity of household consumption basically remained stable and continued to increase, and the high-value areas of the three stages of imbalance, transition and coordinated development remained unchanged. The influencing capacity of industrial support remained basically stable and continued to increase, and the high-value areas of the three stages of imbalance, transition and coordinated development remained unchanged. The influencing capacity of economic security has basically remained stable and has been continuously enhanced. The number of positive areas in the stage of imbalanced development has increased, while the number of high-value areas in the stage of transition and coordinated development has remained basically unchanged.

From the perspective of the coupling and coordination of the supply-demand-support system of cultural tourism in China, the transition from the imbalanced stage to the coordinated development has obvious spatial change characteristics and evolution laws, and based on these change characteristics and trends, the overall development path of the cultural tourism supply-demand-support system has become the key to the transformation and development. In the face of the strategic opportunity and policy orientation of the reconstruction of the supply-demand-support system of cultural tourism, it is particularly important to actively respond to the impact of the new crown epidemic, revitalize the cultural tourism industry system, and combine the relationship between the vulnerability and resilience of the development of the cultural tourism industry. Cultivate more personalized and

localized cultural tourism products, plan a high-quality cultural tourism product system, build a publicity matrix of cultural tourism products, form a three-dimensional guarantee system, and comprehensively help economic and social development. It should take into account its integrated development with science and technology, education, agriculture, ecology and other industries, form a social atmosphere for the development of cultural tourism, take positive measures to deal with the changing market environment, and enhance the competitiveness of cultural tourism. Community” to measure, and to integrate, systematize and standardize the development support and policy supply of the economy and society.

In recent years, the development of China's cultural tourism is facing the strategic opportunities of the development of the digital economy and the strategic background of “double circulation,” which puts forward strategic opportunities and challenges for its transformation and upgrading and high-quality development. In particular, the network traffic hotspots in the cultural tourism market can attract large numbers of people to enter regional tourism destinations. It not only needs to pay attention to the hot spot development and sustainable development of scenic spots (scenic spots), but also needs to pay attention to the supply and demand of cultural tourism in the region and the sustainable development of the whole system. In particular, it is necessary to pay attention to the matching of virtual tourism to space and region (Li Yuan et al., 2024), network attention (Yin Ziyun & Huang Anmin, 2024), presence (Wang Xin & Bai Kai, 2023) and other influencing factors, so as to realize the sustainable development of inter-provincial tourism in China (Yang Yong et al., 2022). Firstly, the dynamic change of cultural tourism economic development is related to many factors such as residents' 'disposable income, residents' leisure time and product supply. We should continue to do a good job in the high-quality development of the supply-side structure of local residents' cultural tourism, meet the needs of local residents and tourists' cultural tourism needs, and maximize the economic and social benefits of cultural tourism products. The market demand in the eastern region is higher than that in the central and western regions, which is an important manifestation of the comprehensive ability of economic and social development. It is necessary to reduce regional differences through the cultivation of local cultural tourism products, the shaping of regional market brands, and the co-construction of eastern, central and western tourist markets. In particular, urban residents in the eastern region, the more economically developed regions, and the denser regions of large urban agglomerations have stronger tourism consumption capacity. They should pay more attention to the design of the path that maximizes the impact on the consumption capacity of these regions, and form an overall improvement in the consumption capacity of cultural tourism products. Secondly, it further analyzes the spatial difference characteristics of cultural tourism in different regions. According to the resource endowment, cultural characteristics, location advantages and economic and social structure of the region, it determines the positioning of cultural tourism development, shapes a series of publicity methods, and improves its attractiveness in the market. In particular, the establishment of brand images such as 'hospitable Shandong' and 'colorful Yunnan', which are very popular in the market, can attract tourists to participate and experience, become an indispensable link in the development of cultural tourism market, and continue to do a good job in the condensation and promotion of cultural tourism brands, so as to ensure the continuous increase of market attraction and realize the sustainable development of cultural tourism.

Conclusions

Based on the coupling coordination theory, this paper constructs the evaluation index system of the supply-demand-support

system of cultural tourism according to the existing research reports, and divides the development stages of the coupling coordination level into three stages: disorderly development, transitional development and coordinated development, and 10 coordination levels of high-quality coordination. The coupling coordination of the supply-demand-support system of cultural tourism has increased from 0.1126 in 2007 to 0.8928 in 2020, with an average value of 0.5882 and an average annual growth rate of 17.27%. The system is in a state of transition from high coupling and low coordination to high coupling and high coordination, and is divided into three development stages: the disorder stage, the transition stage and the coordinated development. The coordination degree develops steadily from moderate imbalance to good coordination in time. The spatial equilibrium characteristics of the supply-demand-support system coupling and coordination of cultural tourism are obvious, and the spatial difference in the western region is getting smaller and smaller, but its relative gap is significantly widened.

This paper explores the coupling and coordination relationship of the supply-demand-support system of cultural tourism, mainly selects the period from 2007 to 2020 as the research period, and takes China as an example, mainly starting from the evaluation time of China's 5A-level tourist attractions and cultural centers as important cultural tourism development carriers. This paper mainly studies the three aspects of product supply, market demand and comprehensive support of regional cultural tourism, and more specifically considers regional development. Therefore, the setting of the index system of historical background, cultural heritage and local cultural policy is not considered in this article. The scope of the follow-up study of our team will strengthen the research in this area. However, in the selection of the index system, it needs to be further optimized, and the provincial scale and type can be selected for comparative research in the selection of case sites, and the coordination level of the supply-demand-support system of cultural tourism can be studied in depth according to the new development stage, statistical data and research methods.

Especially, the indicators of spatio-temporal dynamic analysis (such as the application of the GTWR model) or digital cultural tourism integration are not considered in the research process. Because the article is also in the Tobit regression model to verify the regression results, the verification results are consistent with the results of the regression model, combined with the analysis of the GTWR regression model, due to space constraints, it does not increase the use of VAR model, but also hope to understand, we will continue to pay attention to the application of this method in this field. The data period of this study is from 2007 to 2020, because some cultural tourism index data are missing after 2020. Considering the data availability and index comparability, this paper takes 31 provincial units in China from 2007 to 2020 as the research sample, and the follow-up research period and index system continue to pay attention to enhancing the scientific nature of relevant research.

Data availability

No datasets were generated or analyzed during the current study.

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Author contributions

Zhang Hang and Pu Lili contributed to the study conception, research design, data collection, and data analysis. Zhang Hang wrote the first draft of the manuscript. Pu Lili made the last revisions. Zhang Hang, Chen Xingpeng, and Pu Lili supervised, proofread, and commented on previous versions of this manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

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

Additional information

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