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Article

A Model Study on Maximizing the Synergistic Benefits of Cultural Industry and Tourism Industry in the Context of Big Data

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Abstract: At present, the culture and tourism industry generated by the integration of culture industry and tourism industry has become a new economic growth point, and it is of great significance to study the integrated development of culture and tourism industry. This paper establishes the evaluation model of the integrated development level of culture industry and tourism industry based on the panel data of regional provinces and regions from 2015 to 2024 to quantify the integrated development level of culture industry and tourism industry in regional provinces and regions. Combined with the coupling coordination degree to measure the integration index of cultural industry and tourism industry in regional provinces and districts, and classify the integration degree of cultural industry and tourism industry into grades and stages according to the uniform distribution function method. Analyze the calculation process of the distance synergy model, introduce the TOPSIS method and gray correlation analysis idea into the distance synergy model, and form the distance synergy model based on gray correlation. The optimized distance synergy model is used to quantitatively measure the development of regional synergy benefits. From the results of measuring the integration index, it can be seen that the integration development level of cultural industry and tourism industry in each province and region in the region grows smoothly and continuously over time, and the overall synergy between cultural industry and tourism industry shows a continuous upward trend.

Keywords: distance synergy model; synergy benefit; integrated development level; gray correlation; culture and tourism industry

1. Introduction

Culture is an important source of national cohesion and an important support for national economic strength and international competitiveness. Throughout the history of global social and economic development, cultural industry and tourism industry are important engines for promoting economic growth and improving people's livelihood; tourism, as an ecologically friendly industry, has a strong economic pulling effect, while cultural industry is an industry with high added value [1-4]. The high-quality development of the social economy in the new era requires the cooperation of all regions to promote the quality and efficiency of the economy, and the synergistic development of the cultural industry and tourism industry is a new kinetic energy to promote the high-quality development of the economy in all regions [5-6].

Culture and tourism industry synergy is the integration process of culture industry and tourism industry along with the synergistic effect to realize economic growth, which is essentially the process of culture industry and tourism industry to realize efficient and orderly synergistic growth of factor allocation [7-9]. In the context of the reality of economic transformation, promoting the synergistic growth of the cultural industry and tourism industry is a key path to realize the quality change by high-quality factor allocation change and high-quality synergistic benefit change to promote quality change, and to promote the in-depth integration of culture and tourism and high-quality development

[10-13]. According to the data of the National Bureau of Statistics, both the tourism industry and the cultural industry have achieved rapid development in recent years. However, at present, the development of cultural industry and tourism industry still exists problems such as poor allocation of elements, poor interaction mechanism, and scarce resources, which seriously restricts the synergistic benefits of cultural industry and tourism industry and the high-quality development of industrial integration [14-17].

In the era of big data, we are committed to promoting the digitalization of industry and the high-quality development of digital industry, promoting the integration of online and offline, accelerating the digital development of the cultural industry, expanding the consumption pattern, optimizing the quality of the cultural industry, and the mode of "Internet + Tourism", deepening the digitalization of the tourism industry, and promoting the high-quality development of the tourism industry [18-21]. With the continuous improvement and upgrading of big data technology, the future application of big data in the culture and tourism industry will be more extensive and in-depth, including from promotion and marketing to product design and service innovation [22-23]. By analyzing various data to understand users' needs and preferences, providing personalized recommendations and customized services for users, and helping cultural and tourism organizations to carry out accurate marketing and product design to improve service quality and user satisfaction, big data plays an increasingly important role in the cultural and tourism industry and provides strong support for the synergistic development of the industry.

In recent years, the research on the mutual influence of cultural industry and tourism industry and the development of cultural and tourism products has been more concentrated. Coupling theory, as the mainstream framework for analyzing the two-way interaction between culture industry and tourism industry, has formed a more systematic research paradigm. Relevant digital technologies are combined with traditional analytical theories to provide an in-depth analysis of the synergistic development of the culture and tourism industries. Chi et al. [24] (2022) revealed that the synergy of the culture and tourism industries has a nonlinear economic effect, and that stronger economic effects may be produced in different industry synergy groups due to the application of technology. Bai [25] (2021) pointed out that the degree of integration of the culture and tourism industry significantly promoted the economic benefit growth of the regional tourism industry, and that this benefit growth is more significant when mediated by the level of regional informatization. Zhang [26] (2021) used back-propagation neural network and fuzzy comprehensive analysis to establish a model for evaluating the industrial benefits in the integration of culture and tourism industry in a small town, with social benefits (cultural heritage and protection), environmental benefits (ecological environment improvement), and economic benefits (commercial economic development), and all three benefits reached the level of good or above good. Suciu and Mitucă [27] (2020) demonstrated with the help of museums in the cultural tourism industry that Internet collaboration platforms and technological applications effectively improve social benefits, such as civic education and social cohesion. And Hua and Wangb [28] (2024) revealed that digital technology has displayed museum artifacts in various forms, facilitated the digital transformation of museums, improved tourist participation and communication, led to the development of surrounding businesses, expanded tourism, and promoted the integrated development of culture and tourism and the digital transformation of the culture and tourism industry. Lv et al. [29] (2025) evaluated the local NRM and tourism industry in Jilin synergistic development coupling degree, the overall coupling degree is high, but shows differences in each region of the province, which is due to the differences in the number of non-heritage industries, economic development, government support, etc. Anle et al [30] (2020) pointed out that the culture and tourism industry coupling is strongly driven by consumer demand, and that multidimensional factors such as regional market supply, scientific and technological innovation, policy environment, infrastructure and human resources industry influence the cultural and tourism industry integration. Based on these research backgrounds, the urgency of developing a model to maximize the synergistic benefits of cultural and tourism industries is more reflected, guided by the model results to promote the high-quality development of cultural and tourism industries in each region. In addition, Zhou et al [31] (2020) assessed the coupled and coordinated relationship of culture and tourism industry in ethnic minority regions, the degree of industrial coordination is increasing year by year, but the development of cultural industry is better than tourism industry, and proposed that it is necessary to understand the process of industrial complementarity from the sub-understanding, which contributes to the positive and coordinated development of the industry, and improves the economic and environmental benefits. The big data will integrate and analyze the online and offline data of the development of the culture and tourism industry, which can provide a clearer understanding of the complementary process of industrial synergy, and combine with other digital technologies to accurately match the culture and tourism resources with the tourism scenarios, to develop more cultural and tourism resources, and to promote the maximization of the benefits of the synergistic relationship of the culture and tourism industry.

In the context of big data, Li and Li [32] (2019) constructed a large-scale data platform on cultural

tourism in Dongguan, Guangdong, which collects and analyzes tourists' demand for cultural tourism in Dongguan, and with the help of an intelligent collaborative system of tourism information, synchronizes the demand information to the tourism management department, prompting the department to take corresponding countermeasures. Huo and Wang [33] (2020) emphasized that big data can reshape the supply chain and ecosystem of the cultural and tourism industry, construct tourist portraits based on sharing platforms such as the Internet and incorporate local characteristics and customs to facilitate the development and promotion of cultural and tourism resources and promote the high-quality development of the cultural and tourism industry. Hu et al. [34] (2021) used big data and social network analysis to conduct high-quality and precise Hakka village cultural tourism routes based on tourists' online search data planning, and suggested that the government should give support to the node service center site of the tourism network. Peng [35] (2022) provided tourists with scientific, efficient and personalized featured cultural tourism routes with the help of intelligent algorithms under the background of big data, which improved the quality of tourism services and the operation effect of cultural tourism while promoting the development of featured cultural tourism industry. Bi and Wang [36] (2021) used big data and IoT technology to reconstruct regional cultural resources after the disaster, and constructed a cultural IP development model and a cultural and creative design method, so as to enrich the cultural tourism resources of the region. Popova et al [37] (2023) identified the management risks of digital tourism ecosystems in tourist destinations with the help of big data analysis and IoT, so as to provide an effective management risk control program. Borowiecki et al [38] (2025) used big data to measure cultural tourism in Europe, providing a fine-grained, complete and high-frequency cultural tourism data collection method to obtain a data inventory of all tourist attractions within a given country, which informs the analysis of synergistic benefits of the cultural tourism industry for different attractions. Nuraeni et al [39] (2025) found that in tourism cultural heritage applications and technology applications in marketing can effectively enhance local tourist engagement and competitiveness, and big data analysis based on market and consumption data can be used for marketing strategy planning and market segmentation, while digital narratives and virtual presentations of cultural heritage can be realized with the help of artificial intelligence, augmented reality, and virtual reality.

This paper captures the resource characteristics, industrial characteristics and product characteristics of cultural industry and tourism industry. It analyzes the connotation and characteristics of synergistic benefits, combines the theoretical support and realistic development of the integration of cultural industry and tourism industry, and proposes to measure the maximum benefits of the synergistic development of cultural and tourism industries by establishing the evaluation model of the comprehensive development level of cultural industry and tourism industry. The coupling coordination degree model is used to measure the index of the integration degree of cultural industry and tourism industry in each province and district in the region. The optimized distance synergy model about grey correlation is used to calculate the degree of synergistic development of culture and tourism industries in the region from 2015 to 2024, and the evaluation results of the development of regional synergistic benefits in the past years are obtained.

2. Basis for the development of industrial synergies

2.1. Cultural industries

Cultural industries are those cultural business institutions that operate for profit, including cultural institutions of public interest, State organizations and non-profit organizations. These organizations are closely related to social production such as advertising, radio and television broadcasting, and performing arts. The cultural activities of all these organizations are ultimately presented to the public in the form of product entities. Therefore, the cultural industry is mainly used as an economic concept, while the level of its development will be evaluated and analyzed in this paper by taking the level of revenue, the number of institutions, the number of employees, and the business situation of the cultural industry as indicators [40-41].

2.2. Tourism industry

The tourism industry is composed of the tourism industry itself as well as the upstream and downstream related industrial entities that provide services, products and facilities for tourism. This paper also focuses on assessing the development of the tourism industry through the economic benefits of tourism, the number of employment, the industry sector and the pull on upstream and downstream industries [42-43].

2.3. Industrial characterization

2.3.1. Characteristics of the tourism industry

(1) Resource characteristics: borderlessness

Tourism resources are characterized by borderlessness. Tourism resources are both natural resources and human resources. There are both static display-type resources and dynamic participatory resources. The form and type of tourism resources are different, but their common characteristic is attractive. As long as the tourists have attraction, any things and factors can be utilized for tourism, tourism resources have significant characteristics of no boundary.

(2) Industrial characteristics

Cultural: tourism demand and tourism resources have cultural attributes.

High complexity: tourism is defined based on tourists' demand and tourism activities, thus tourism is characterized by high degree of association, comprehensiveness and integration.

Free mobility of industrial elements: there is a development trend of free mobility and integration and synergy among the elements within the tourism industry. As people's income improves and their ability to travel increases, the strong demand-driven mechanism promotes the free flow and optimal allocation of all elements of the tourism industry, realizing a reasonable division of labor and collaboration in the tourism industry, so as to maximize its benefits.

The current industry linkage development mode accelerates the flow of tourism elements between industries and promotes the organic integration between tourism industry and other industries.

(3) Product Characteristics

The latent nature of attraction: due to the constraints of space, culture, communication and other factors, the radiation range of the attraction of tourism products is affected to a certain extent. Both the public and tourist destinations need a medium to convey the real condition of the tourist place, which reduces the latent degree of attraction of tourism products. Many tourism products require tourists to be present in order to really feel their attraction, and in the absence of a comprehensive display and marketing conditions, the attractiveness of these tourism products has a latent nature.

The homogeneity of production, sales and consumption: the homogeneity of production, sales and consumption of tourism products objectively puts forward higher requirements for the supply and service of tourism products, and requires that they can be adapted to the needs of tourists. However, due to the seasonality of the tourism industry and the volatility of demand, it makes the supply and demand of tourism products always unbalanced.

2.3.2. Characteristics of cultural industries

(1) Characteristics of resources: need to show

Convert cultural resources into cultural products, need to externalize the cultural connotation and value contained in the resources themselves, so that they are recognized by society, so that cultural products can be sold to achieve their own value. If the cultural resources cannot be externalized and displayed, the resources only stay at the level of potential to be developed, and cannot be put into circulation.

(2) Industrial characteristics

Convenience: The Internet has become the most active medium for cultural products, satisfying the diversified demands for culture with its fast and high-quality services.

Strong integration: the strong integration of cultural industry depends on its high industrial correlation and strong industrial permeability.

Due to the wide extension of cultural industry, it can be connected with many industries, thus prompting the penetration of cultural resources into other industries, gradually blurring the industrial boundaries and continuously extending the industrial chain.

(3) Product characteristics

Strong attraction: cultural industry includes many kinds of industries, which possess both tangible material cultural heritage resources and intangible spiritual cultural heritage resources, and have strong attraction to the public.

2.4. Synergies

Synergistic benefits were first proposed by the Intergovernmental Panel on Climate Change (IPCC) in the 1990s. Initially, it referred to the incidental benefits of measures to reduce greenhouse gas emissions, such as the reduction of local air pollutants and the health of the population. Later, it was widely used in the field of environment, and gradually penetrated into economics, management and other humanities and social sciences fields, and the meaning was expanded. The incidental benefits of one or some activities, measures, functions, etc. of an organization on other related activities. Mainly has the following characteristics:

(1) The design of benefits. The organization in the measures, activities, functions in the formulation of the place through certain means to clarify the synergistic benefits.

(2) The collateral nature of the benefits. The benefits generated by synergies are incidental and "unintentional", but not necessarily passive.

(3) Benefits generated by the main body of the singularity and unidirectionality. The main body of the synergistic benefits is generally a single subject, through a unidirectional way to act on the object.

(4) The correlation between the subject and object of benefits. The realization of synergistic benefits needs to be based on the correlation between the subject and object of benefits.

2.5. Integration and development of cultural industry and tourism industry

Industrial integration is a new development model, which is of great significance for the development of an innovative economy and the promotion of the transformation of industrial structure. After industrial integration reaches a certain degree, new industries or new economic growth points will be generated. This paper mainly studies the mutual integration of cultural industry and tourism industry.

Combined with the concept of industrial integration, this paper argues that the concept of cultural and tourism integration should be the interpenetration, intersection, integration and reorganization of two mutually independent systems of culture and tourism, gradually breaking through the original boundaries, and intermingling to form a new symbiosis or a new industry. The ultimate goal of culture industry and tourism industry is to provide products and services for the society, and both of them are highly correlated in terms of resources, technology and market.

(1) Theoretical basis

Industrial integration refers to the process of promoting the development of industry and continuously improving competitiveness, which makes industry and industry cross and penetrate each other in the process of development, so that the boundaries of industry are gradually blurred or disappeared, and finally reconfigured to form a new form through a dynamic development.

Industrial integration has three characteristics: it is difficult to delineate industrial boundaries in the process of dynamic development. New forms of business can be created through industrial integration. The evolution process is always changing.

In industrial integration, relevance, marketability and dynamism are important prerequisites. Relevance refers to the fact that there must be a link between the industries that are converging, which can be related to technology, industrial chain, or the complementarity of industrial resources, the consistency of supply and demand, and so on. Marketability refers to the fact that enterprises in all industries compete in the market, and industrial integration is a way to help them increase their competitive advantages. Dynamism means that industrial integration does not add up certain industries arbitrarily, but integrates them selectively, while changing dynamically according to market supply and demand, and ultimately realizing the multiplier effect of integration.

(2) Realistic development

With the increasingly fierce competition in the culture and tourism market, more and more cities have gradually become cultural tourism destinations with huge scale and perfect facilities, and the regional culture industry and tourism industry have gradually become mature integrated development industries.

Over time, many provinces and cities have been able to innovate and develop various forms of products and services, such as ethnic culture and festival tourism. In addition, with the evolution of cultural tourism consumption demand, the production factors required on the supply side of cultural tourism products are bound to undergo more changes. In this context, the market integration of cultural tourism centered on tourism demand has become the main direction of cultural tourism product development in the new era. And with the development of society and the improvement of people's living standards, more and more tourists begin to pay attention to those tourism activities that are different in the spiritual and cultural level.

3. Measuring the development of industrial synergies

3.1. Measurement of the Coordination Relationship between Cultural Industry and Tourism Industry

3.1.1. Comprehensive evaluation index system construction

Cultural industry and tourism industry are two complex systems, in order to objectively reflect the development level of cultural and tourism industry, this paper follows the principles of scientific, operability and systematic, in order to effectively measure the level of integrated development of cultural and tourism industry, and to lay a scientific data foundation for the subsequent research.

The development of culture and tourism industries involves resource endowment, economic

development, policy environment, etc. The DSR model is proposed by the United Nations Commission on Sustainable Development, widely used in ecological environment evaluation, etc., and then expanded to the evaluation of tourism industry development, etc. The DSR model consists of driving force, state, and response, which constitutes an organic system reflecting the dynamic characteristics of each. The model reflects the interrelationships and influences between industrial development, and provides a basic framework for measuring the comprehensive development level of cultural industry and tourism industry.

The indicators for measuring the development level of cultural industry are shown in Table 1.

Table 1. Index of development level of cultural industry.

Industry	Serial number	Evaluation index
Cultural industry Q1	Q11	Local cultural industry practitioners
	Q12	Cultural resource density
	Q13	Cultural industry general production
	Q14	Number of cultural administrative institutions
	Q15	Cultural resource taste
	Q16	Number of museums
	Q17	Number of public libraries
	Q18	The number of art exhibition groups
	Q19	The number of art exhibition groups

The index system for measuring the level of tourism industry development is shown in Table 2.

Table 2. Index system of tourism industry development level.

Industry	Serial number	Evaluation index
Tourism industry Q2	Q21	Number of tourist practitioners
	Q22	Tourist resource taste
	Q23	Tourist resource density
	Q24	Domestic travel income
	Q25	Travel income
	Q26	The number of tourist spots in a
	Q27	Tourism management department
	Q28	Number of star hotels
	Q29	Number of travel agents

The formula for calculating the degree of taste for cultural resources is:

$$C = \frac{N_i}{\sum_{i=1}^{9} N_i} \times 100 \tag{1}$$

In the above formula, C is the degree of taste of cultural resources, and N_i is the number of cultural resources in the i th municipality.

The formula for calculating the taste degree of tourism resources is:

$$T = \frac{P_i}{\sum_{i=1}^{9} P_i} \times 100 \tag{2}$$

In the above formula, T is the degree of taste of tourism resources, and P_i is the number of tourism resources in the i th municipality.

Considering the inconsistency between the indicators of culture and tourism industry, in order to ensure the scientificity of the integrated development level of culture and tourism industry, the indicators are standardized. This paper applies the entropy value method to measure the weights of the indicators.

STEP1: Perform homogenization of heterogeneous indicators.

Positive indicators:

$$X_{ij} = \frac{y_{ij} - \min(y_{ij})}{\max(y_{ij}) - \min(y_{ij})} \tag{3}$$

where i denotes the i th year and j denotes the j th indicator. $\max(y_{ij})$, $\min(y_{ij})$ are the maximum and minimum values of the indicator j.

STEP2: Calculate the weight of the j th indicator in the i th province:

$$Z_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{4}$$

STEP3: Calculate the entropy value of the j th indicator:

$$E_j = -k\sum_{i=1}^{m} Z_{ij} \ln\left(Z_{ij}\right) \tag{5}$$

where E_j is the entropy value of indicator j and $E_j > 0$.

STEP4: Calculate the coefficient of variation:

$$G_i = 1 - E_j \tag{6}$$

STEP5: Calculate the j th indicator weight:

$$w_j = \frac{G_j}{\sum_{j=1}^{n} G_j} \tag{7}$$

After standardizing the raw data, according to the above formula, the indicator weights of the cultural industry and tourism industry in each province and district of the study region from 2015 to 2024 can be calculated.

The indicator weights of the cultural industry and tourism industry in the region are shown in Figure 1, where S represents the development level of the cultural industry and tourism industry in the region, and Q1 and Q2 represent the cultural industry and tourism industry, respectively. From the figure, it can be seen that in Q1 cultural industry, the indicator weight of Q16 number of museums is 0.2403, and the number of museums can better represent the level of development of cultural industry in the region.

Figure 1. Regional cultural industry and tourism industry index weight.

3.1.2. Comprehensive evaluation model construction

The evaluation function for the comprehensive development of the cultural industry is:

$$f(x) = \sum_{j=1}^{n} a_j X_j \tag{8}$$

In the formula, j is the characteristic indicator of the cultural industry system, and n is the total number of indicators included in the cultural industry system. a_j is the proportion of the indicators selected from the cultural subsystem in the comprehensive development evaluation, i.e., the weight, which is used to measure the degree of importance of each characteristic indicator in the system. X_j is the value of the j standardized indicator describing the characteristics of the cultural industry system. The higher the value of the comprehensive development index of cultural industry calculated according to the evaluation function, the better the comprehensive development of cultural industry is. The lower the value of comprehensive development index of cultural industry, the worse the comprehensive development status of cultural industry.

Similarly, the evaluation function of comprehensive development of tourism industry can be obtained as follows:

$$g(y) = \sum_{j=1}^{n} b_j Y_j \tag{9}$$

In the formula j is the characteristic indicators of the tourism industry system, n is the total number of indicators included in the cultural industry system. b_j is the proportion of indicators selected from the tourism sub-system in the comprehensive development evaluation, i.e., the weight, which is used to measure the degree of importance of each characteristic indicator in the system. Y_j is the value of the j standardized indicator describing the characteristics of the cultural industry system. The higher the value of the comprehensive development evaluation index of tourism industry calculated according to the evaluation function, the better the development status of tourism industry. On the contrary, it indicates that the development condition of tourism industry is worse.

3.1.3. Measurement and analysis of results

The comprehensive development level evaluation model is used to measure the index of comprehensive development level of cultural industry in provinces and cities in a region, and the results of measuring the comprehensive development level of cultural industry are shown in Figure 2.

The index of comprehensive development level of cultural industry of nine provinces and regions in the region shows an overall upward trend, but the development level is low and the development within the region is extremely unbalanced.

The index of comprehensive development level of cultural industry in QH province always stays below 0.080, and the comprehensive development level of cultural industry in QH province is low compared with other provinces and regions in the region.

The comprehensive development level index of cultural industry in SC, HN and SD provinces is always higher than 0.4 after 2019.Especially in HN and SD provinces, the comprehensive development level index of cultural industry in the two provinces reached 0.642 and 0.671 respectively in 2019, with good comprehensive development of cultural industry.

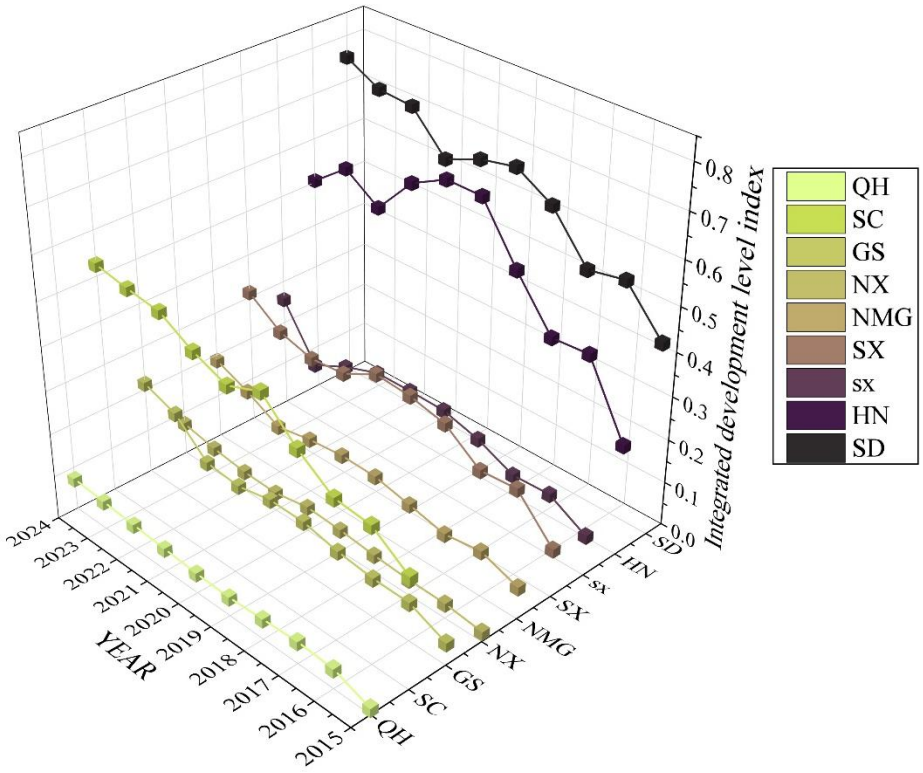

Figure 2. The comprehensive development of cultural industry measures the results.

The results of measuring the comprehensive development level of tourism industry are shown in Figure 3.

In 2024, the index of comprehensive development level of tourism industry in QH province is 0.075. The comprehensive development of tourism industry and cultural industry in QH province are relatively balanced.

The index of comprehensive development level of tourism industry in SC, SX, HN and SD provinces is relatively high, which is 0.319, 0.267, 0.231 and 0.324 respectively in 2024.

NX province has a lower level of comprehensive development of tourism industry, and in 2024, the index of comprehensive development level of tourism industry is only 0.049.

During the period from 2015 to 2024, the trend of the comprehensive development level of tourism industry in SD, SC and SX provinces is large.

Overall, the comprehensive development level of the tourism industry in the provinces and districts in the region generally showed an upward trend from 2015 to 2024.

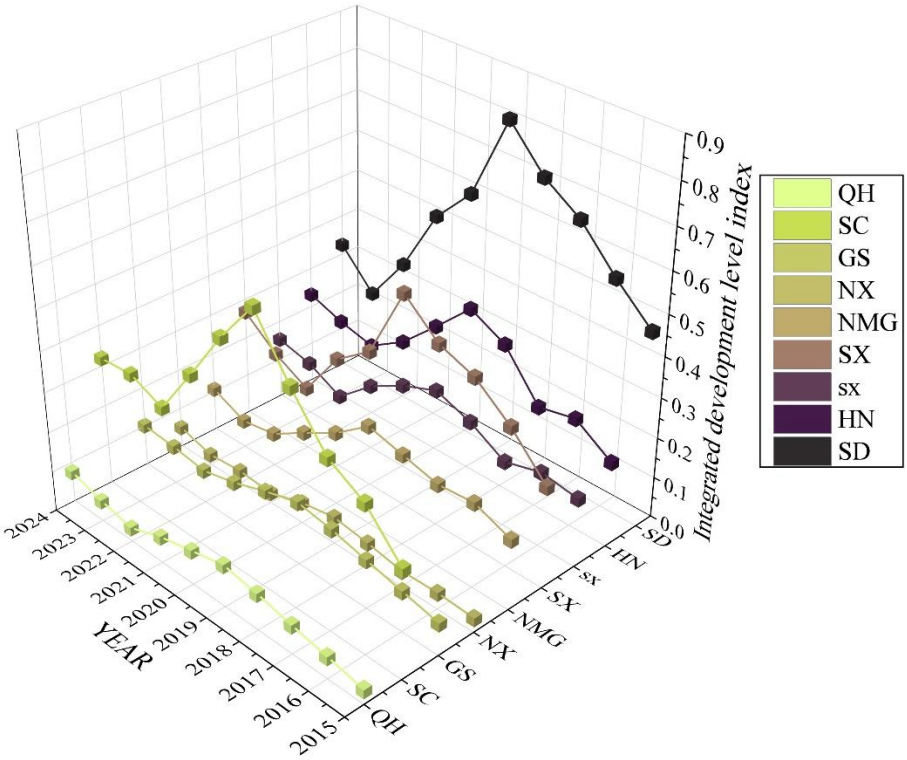

Figure 3. The tourism industry comprehensive development level measure results.

The coupled coordination degree model was used to measure the index of the integration degree of cultural industry and tourism industry in the provinces and districts in the region, and the relative development degree model was used to measure their relative development levels and classify the integration types. The uniform distribution function method is used to classify the grades and stages of the integration degree of cultural industry and tourism industry. The rating criteria for the integration degree of cultural industry and tourism industry are shown in Table 3.

Table 3. Standards for the grading of cultural and tourism industries.

Fusion level	Fusion phase	Degree of fusion
Extreme dissonance	Germination	[0,0.1)
Severe disorder		[0.1.0.2)
Moderate disorder		[0.2,0.3)
Mild disorder		[0.3,0.4)
On the brink	Initial stage	[0.4,0.5)
Grudging		[0.5,0.6)
Primary coordination	Stabilization phase	[0.6,0.7)
Intermediate coordination		[0.7,0.8)
Good coordination	Mature stage	[0.8,0.9)
Quality coordination		[0.9,1)

The results of the index measurement of the integration of cultural industry and tourism industry are shown in Figure 4.

From the measurement results, it can be seen that the integration development level of cultural industry and tourism industry in the provinces and regions in the region has been growing steadily and continuously with the passage of time.

Specifically, the integration index, integration level, integration stage and integration type of the cultural industry and tourism industry of the provinces and regions in the region present the following characteristics:

(1) The integration index of the industry and tourism industry of the provinces and regions in the region shows a rising trend year by year, but there are large differences within the region.In 2015, the integration development level of the cultural industry and tourism industry of the provinces and regions in the region was not high in general, and the only ones with an integration index higher than 0.5 were the

provinces of SC and SD.The level of the integration development of the cultural industry and tourism industry of the provinces and regions in 2018 and 2021 has been improved. Among them, the development of SD province is more prominent in 2018, and the integration index of cultural industry and tourism industry is 0.754. In 2021, the integration index reaches 0.871.

(2) From the perspective of integration level, the integration level of cultural industry and tourism industry of the provinces and regions in the region has been increasing over time. in 2015, more than two-thirds of the areas in the provinces and regions in the region were in the state of dysfunction in the integration and development of the cultural industry and tourism industry, and only SC province and SD province were in the state of barely coordinated and primary coordinated, respectively.

In 2024, QH, GS, NX, and NMG provinces are still in the budding stage, i.e., the integration degree is less than 0.4. The integration degree of cultural industry and tourism industry in SC, HN, and SD provinces is 0.614, 0.525, and 0.694 respectively, which are in the state of primary coordination, barely coordinated, and primary coordinated respectively.

By 2024, the integration degree of cultural industry and tourism industry in the provinces and districts in the region can be slowly improved compared with 2015.

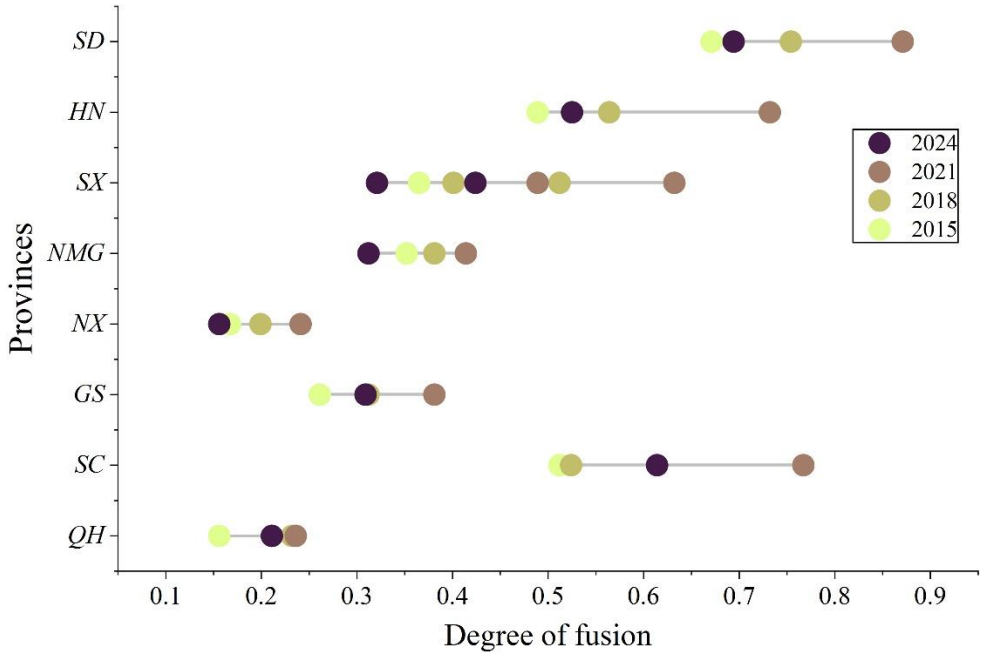

Figure 4. Index measure of cultural industry and tourism industry.

3.2. Analysis of synergy between cultural industry and tourism industry

3.2.1. Gray correlation based distance synergy modeling

The distance synergy model is a model that measures the level of synergy of a system by calculating the Euclidean distance between the actual state and the ideal state of the overall system. In the Distance Synergy Model, there are three metrics: degree of development, degree of synergy, and degree of synergistic development.

The distance synergy model has the following six calculation steps:

Step1: Normalize the subsystem data

Step2: Calculate the actual development degree of subsystems and the overall system.

According to the entropy value method, the indicator weight $w\_x_{km\ t}$ of the subsystem indicator $x_{km\ t}$ is calculated, and the data $s\_x_{km\ t}$ of the subsystems after standardization is weighted, so as to get the degree of development of each subsystem DV_{kt}. The formula for calculating the development degree DV_{kt} of each subsystem is shown in (10):

$$DV_{kt} = \sum_{m=1}^{n} w_{x_{km}}\ s\_x_{km\,t} \tag{10}$$

Step3: Calculate the ideal development degree of each subsystem.

The overall system consists of a total of c subsystems, then the development degree DV_t of the overall system is:

$$DV_t = \frac{1}{c}\sum_{k=1}^{c} DV_{kt} \tag{11}$$

Step4: Calculate the Euclidean distance between the actual development degree and the ideal development degree.

Calculate the distance S_t between the actual development degree DV_{kt} and the ideal development degree DV_t of the overall system as shown in the following equation:

$$S_t = \sqrt{\sum_{t=1}^{c}(DV_{kt} - DV_t)^2} \tag{12}$$

When S_t is larger, which represents the larger distance between the actual development degree and the ideal development degree, the overall system synergy level is lower.

Step5: Calculate the distance synergy

The formula for calculating the distance synergy degree τ_t of the system is shown in (13):

$$\tau_t = 1 - S_t \tag{13}$$

Step6: Calculate the synergistic development degree of the system

The formula for the synergistic development degree τDV_t of the system is shown in (14):

$$\tau DV_t = \sqrt{DV_t \tau_t} \tag{14}$$

The value range of synergy development degree τDV_t is $[0,1]$, and the larger value of τDV_t represents the higher degree of synergy development of the system.

The idea of TOPSIS method and the idea of gray correlation analysis are introduced into the distance synergy model, and the distance synergy model based on gray correlation is composed. The calculation includes the following six steps:

Step1: Standardization of subsystem data. The standardization processing method is the same as the above equation, and the standardized data is noted as $s\_x_{km\,t}$.

Step2: The entropy value method is assigned, and the weighted subsystem standardized data is calculated and noted as $ws\_x_{km\,t}$.

Step3: Calculate the positive ideal point and negative ideal point. Based on the idea of TOPSIS, positive ideal point and negative ideal point are introduced in the model. Positive ideal point is the set of optimal values of each index, which is denoted as L^+. The negative ideal point is the set of the worst value of each indicator, which is denoted as L^-, as shown in equations (15) and (16):

$$\begin{aligned} L^+ &= \left(\max w\_s_{x_{k1}}, \max w\_s_{x_{k2}}, \ldots, \max w\_s_{x_{kn}}\right) \\ &= \left(ws_1^+, ws_2^+, \ldots, ws_n^+\right) \end{aligned} \tag{15}$$

$$\begin{aligned} L^- &= \left(\min w\_s_{x_{k1}}, \min w\_s_{x_{k2}}, \ldots, \min w\_s_{x_{kn}}\right) \\ &= \left(ws_1^-, ws_2^-, \ldots, ws_n^-\right) \end{aligned} \tag{16}$$

Step4: Calculate the development degree of the overall system and subsystems

①Calculate the Euclidean distance S_{kt}^+ between each indicator of the subsystem and the positive ideal point and the Euclidean distance S_{kt}^- between the subsystem and the negative ideal point at the time of t period, the formula is shown in (17):

$$S_{kt}^{+}=\sqrt{\sum_{m=1}^{n}\left(ws\_x_{km\,t}-ws_1^{+}\right)^2},\ S_{kt}^{-}=\sqrt{\sum_{m=1}^{n}\left(ws\_x_{km\,t}-ws_1^{-}\right)^2} \tag{17}$$

② Calculate the degree of development of the subsystem

The subsystem development degree D_{kt} is calculated as shown in (18):

$$D_{kt}=\frac{S_{kt}^{-}}{S_{kt}^{+}+S_{kt}^{-}} \tag{18}$$

The range of values for the degree of development of the subsystem is $[0,1]$ and the larger the value of the degree of development of the subsystem indicates the higher the degree of development of the subsystem.

③Calculate the overall system development degree

The overall system consists of c subsystems, then the development degree D_t of the system is calculated as shown in (19):

$$D_t=\sqrt[c]{\prod_{k=1}^{c}D_{kt}} \tag{19}$$

Step5: Calculate the ideal development degree of subsystems

①Calculate the gray absolute correlation degree between subsystems

Notate the set of D_{kt} calculated according to Eq. (18) as $D_k=\left(D_{k1},D_{k2},\ldots,D_{km}\right)$, and do the transformation of this set as shown in Eq. (20):

$$\begin{aligned}D_k'&=\left(D_{k1}-D_{k1},D_{k2}-D_{k1},\ldots,D_{km}-D_{k1}\right)\\&=\left(D_{k1}',D_{k2}',\ldots,D_{km}'\right)\end{aligned} \tag{20}$$

Order:

$$\left|\beta_k'\right|=\left|\sum_{t=2}^{m-1}D_{kt}'+\frac{1}{2}D_{km}'\right| \tag{21}$$

$$\left|\beta_k'-\beta_l'\right|=\left|\sum_{t=2}^{m-1}\left(D_{kt}'-D_{lt}'\right)+\frac{1}{2}\left(D_{km}'-D_{lm}'\right)\right| \tag{22}$$

Then the absolute correlation AC_{kl} between subsystems is:

$$AC_{kl}=\frac{1+\left|\beta_k'\right|+\left|\beta_l'\right|}{1+\left|\beta_k'\right|+\left|\beta_l'\right|+\left|\beta_k'-\beta_l'\right|} \tag{23}$$

② Calculate the gray relative correlation between the subsystems

Notate the set of subsystem development degree D_k calculated according to Eq. (18) as $D_k=\left(D_{k1},D_{k2},\ldots,D_{km}\right)$, and do the transformation of this set as shown in Eq. (24):

$$D_k''=\left(\frac{D_{k1}}{D_{k1}},\frac{D_{k2}}{D_{k1}},\ldots,\frac{D_{km}}{D_{k1}}\right)=\left(D_{k1}'',D_{k2}'',\ldots,D_{km}''\right) \tag{24}$$

Order:

$$\left|\beta_k''\right|=\left|\sum_{t=2}^{m-1}D_{kt}''+\frac{1}{2}D_{km}''\right| \tag{25}$$

$$\left|\beta_k''-\beta_l''\right|=\left|\sum_{t=2}^{m-1}\left(D_{kt}''-D_{lt}''\right)+\frac{1}{2}\left(D_{km}''-D_{lm}''\right)\right| \tag{26}$$

Then the gray relative correlation RC_{kl} between subsystem k and subsystem l is:

$$RC_{kl} = \frac{1+\left|\beta_k''\right|+\left|\beta_l''\right|}{1+\left|\beta_k''\right|+\left|\beta_l''\right|+\left|\beta_k''-\beta_l''\right|} \tag{27}$$

③ Calculate the gray composite correlation RC_{kl} of the subsystems, as shown in (28):

$$RC_{kl} = \theta AC_{kl} + (1-\theta)RC_{kl} \tag{28}$$

where θ is the degree of attention to the gray absolute correlation and gray relative correlation in the gray composite correlation, in the research of this paper, the degree of attention to the two correlations is the same, so take the value of θ as 0.5.

④ Calculate the ideal development degree of the subsystem

In order to reflect the synergistic relationship, a pull factor f_{kl} indicating the interaction between subsystems is introduced, which represents the pull coefficient of subsystem k to subsystem l. The development of different subsystems is different, and the interaction between these subsystems can make them realize the synergistic state. The value of pull factor f_{kl} is shown in equation (29):

$$f_{kl} = \begin{cases} RC_{kl}, & D_{lt} > D_{kt} \\ 1, & D_{lt} = D_{kt} \\ \dfrac{1}{RC_{kl}}, & D_{lt} < D_{kt} \end{cases} \tag{29}$$

Then the desired development degree D_{kt}^* of subsystem k is:

$$D_{kt}^* = \sum_{l=1}^{c} f_{kl} D_{lt} \tag{30}$$

Step6: Calculate the degree of synergy of the overall system and the degree of synergistic development

Calculate the synergy degree E_{kt} of the subsystems, the formula is shown in (31):

$$E_{kt} = \frac{\left|D_{kt}\right|}{\left|D_{kt}\right|+\left|D_{kt}-D_{kt}^*\right|} \tag{31}$$

Calculate the degree of synergy E_t of the overall system as shown in (32):

$$E_t = \sqrt[c]{\prod_{k=1}^{c} E_{kt}} \tag{32}$$

Then the degree of synergistic development of the overall system ED_t is:

$$ED_t = \sqrt{E_t D_t} \tag{33}$$

The value of the degree of synergistic development ED_t ranges from $[0,1]$, the larger the value, the more synergistic development of the system is represented.

3.2.2. Degree of synergy and synergy development

According to the gray correlation-based distance synergy development evaluation model constructed above, the panel data of the synergy development area of each province and district in the region from 2015-2024 are brought into the calculation, and the quantitative evaluation results of the level of synergy development in the past years can be obtained. Here, QH, SC, GS, HN, and SD provinces are selected as the main research provinces to develop the development evaluation of the synergy benefit development status of cultural industry and tourism industry in these five provinces.

The pull factor between the regional subsystems in the synergistic development area is shown in Fig. 5. The pull factor between QH province and SC province is 0.5826, which is higher than the pull factor between QH province and other provinces. It indicates that the development of industrial interaction between the two provinces of QH province and SC province is more coordinated. Combining the inter-system pull factor between SC province and other provinces, it can be seen that SC province has a greater development momentum.

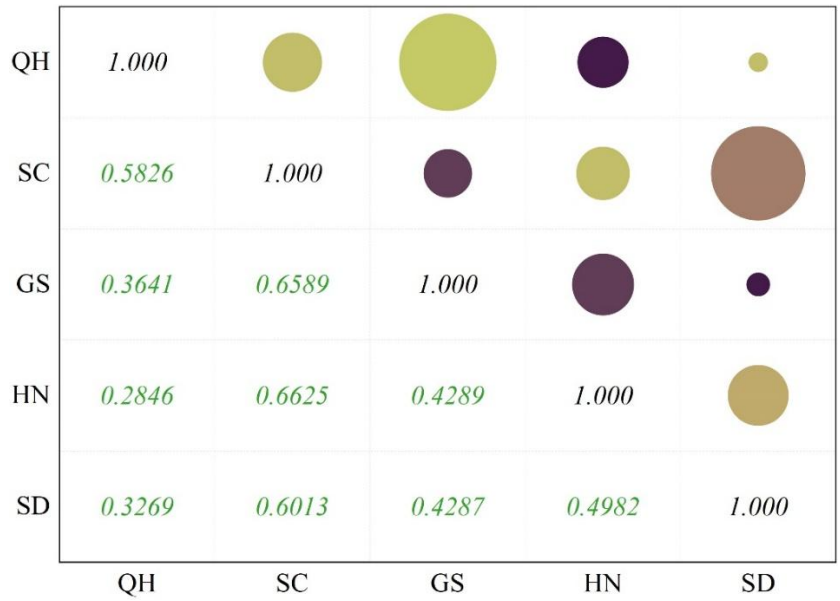

Figure 5. Pull factors between the domain subsystems in each area.

The degree of subsystem development in the regions of the Synergy Development Zone is shown in Figure 6. The subsystem development degree of each province in the region has a general upward trend in the period of 2015-2024. The coordinated development of cultural industry and tourism industry is better in SC and SD provinces.

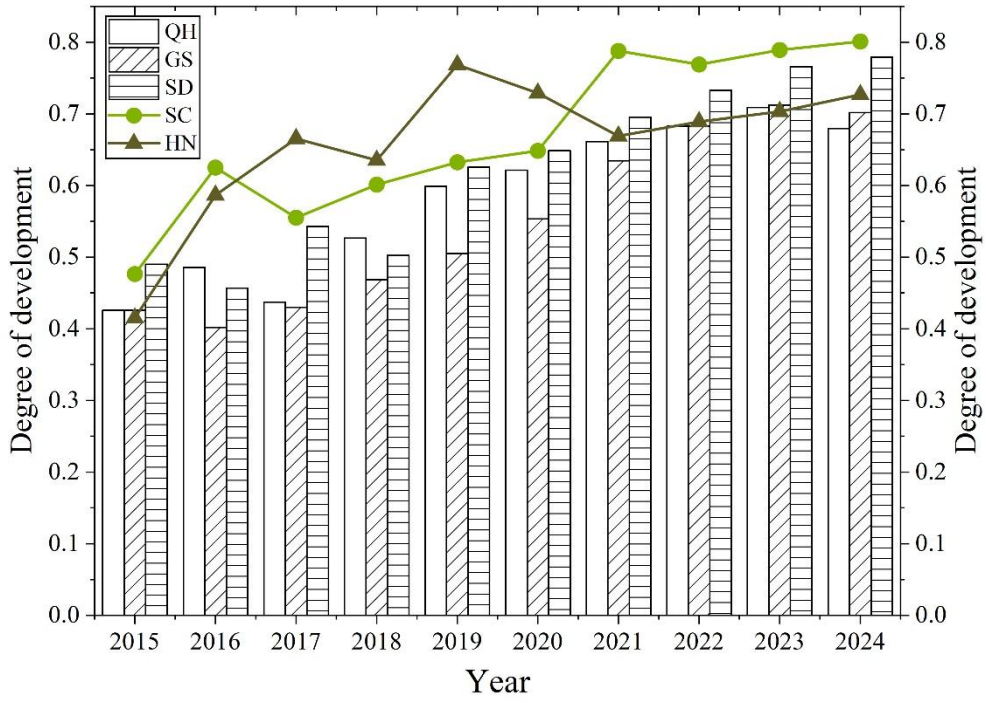

Figure 6. The development of regional subsystems in the collaborative development area.

The degree of synergy of the regional subsystems in the synergistic development zone is shown in

Figure 7. Overall, the synergy degree of culture industry and tourism industry in the provinces and districts in the region shows a continuous upward trend.

Taking SC province as an example, the synergistic degree of culture industry and tourism industry in the province was 0.4701 in 2015, and the synergistic development of culture and tourism industry was in a relatively stable stage. 2022 saw a small decrease, and then it was improved in 2023 until the synergistic degree of culture industry and tourism industry was 0.7563 in 2024, which was a good development trend.

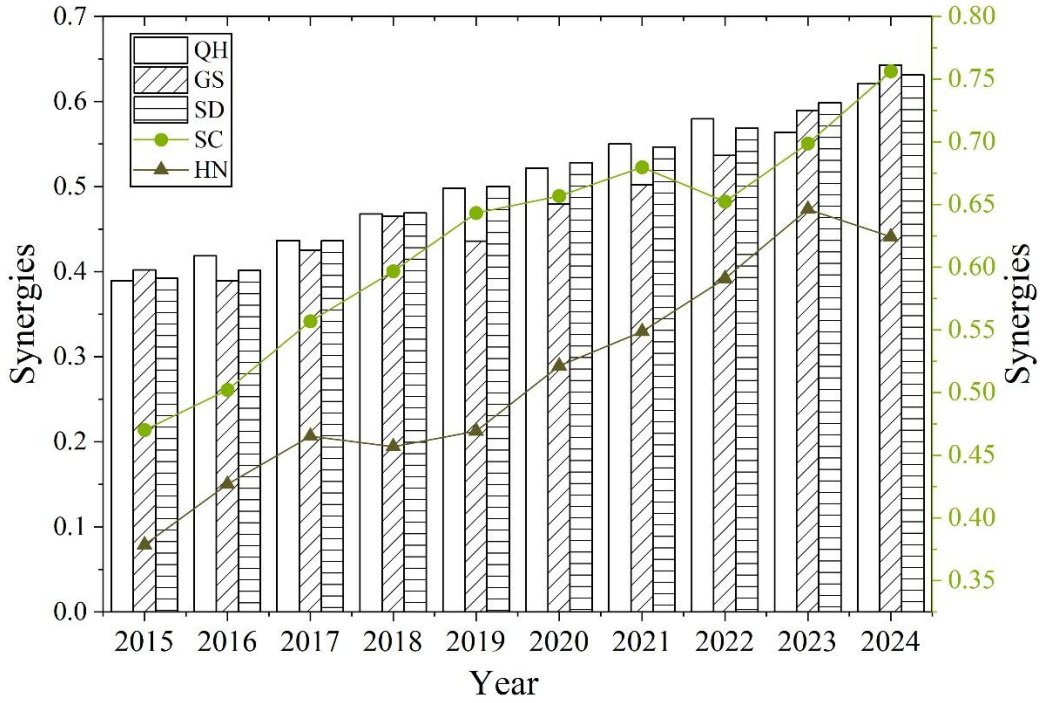

Figure 7. Coordination of domain subsystem in the cooperative development area.

The overall development degree, overall synergy and synergistic development degree of the synergistic development area are shown in Figure 8. The overall synergy development degree of the region reaches more than 0.7 in 2024.

In terms of the correlation between development degree and synergy degree. Whether for the region as a whole or the subsystems, the development degree and synergy degree basically show a relatively consistent trend of change, and there is a strong correlation between them.

Taking the synergistic development area composite system as a whole as an example, the development degree of the regional whole, the overall synergistic degree and the synergistic development degree declined in individual years, and all of them also improved in the following year. 2015-2024, all three of them consistently and steadily increased. The above illustrates that regional development and regional synergy are complementary and mutually reinforcing, and that inter-regional synergy and mutually beneficial symbiosis promote orderly regional development. Comprehensive and stable regional socio-economic development lays the material foundation and good guarantee for regional interoperability and synergy.

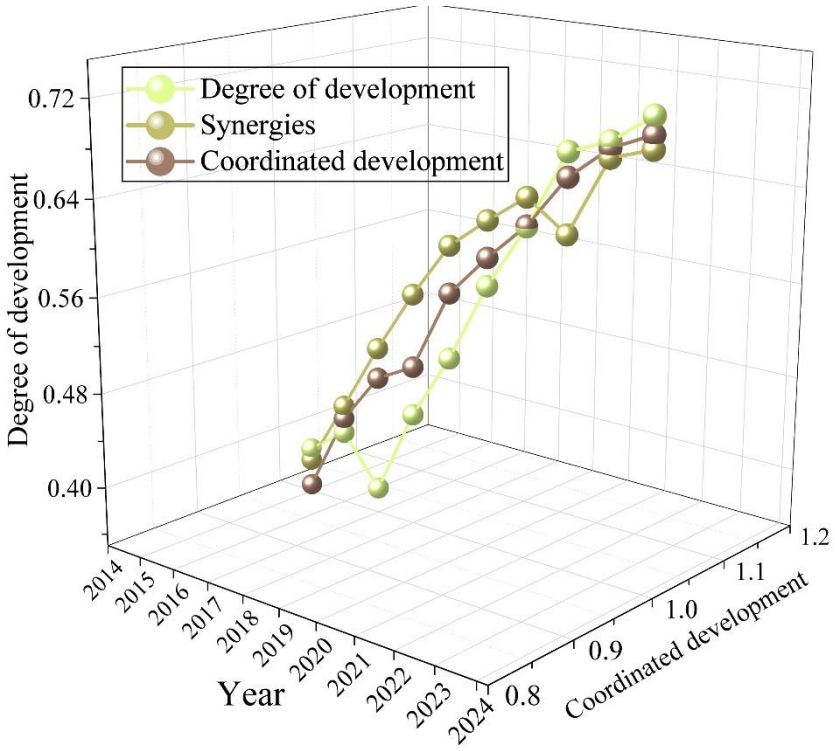

Figure 8. The coordinated development of the collaborative development zone.

4. Conclusion

This paper determines the comprehensive development level of cultural industry and tourism industry, and measures the integration index of cultural industry and tourism industry in each province and district in the region using the coupling coordination degree model. The distance synergy degree model is improved to analyze the overall development degree, overall synergy degree and synergistic development degree of the provinces and districts in the region.

(1) The comprehensive development level evaluation model measurement shows that the comprehensive development level index of cultural industry in nine provinces and regions in the region is on the rise as a whole, but the development level is low and the development within the region is extremely unbalanced. Among them, the cultural industry of QH province develops more slowly. Combined with the results of measuring the comprehensive development level of tourism industry, the development of culture industry and tourism industry in QH province is relatively balanced.

(2) Within the regional synergistic development area, there is a system development pull factor of 0.5826 between QH province and SC province.From 2015 to 2024, the sub-system development degree of the regional synergistic development area shows an overall upward trend. The overall regional synergy development degree reaches more than 0.7 in 2024.

There is a strong correlation between the degree of regional development and the degree of synergy, combined with the results of the distance synergy model measurement based on gray correlation, the development of regional provinces and regions to maximize the synergistic benefits can be implemented into the cultural industry, tourism industry comprehensive evaluation of the indicators, to enhance the synergistic benefits from the level of development.

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