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Big Data Computational Analysis of the Spatial Distribution and Coupling Characteristics of the Sports and Tourism Industries

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Abstract Promoting the integrated development of “sports, culture and tourism” industry is not only a practical need for upgrading the consumption structure of the public, but also an inevitable requirement to meet the people's aspirations for a better life. On the basis of constructing the evaluation index system for the development of sports industry and tourism industry, the entropy weight TOPSIS method, coupling coordination model, Kernel density estimation, Dagum Gini coefficient method, σ-convergence method, and spatial β-convergence method are applied to explore the spatio-temporal dynamic evolution trajectory, regional variability source and convergence effect of the coupling coordination degree of sports and tourism industry in 31 provinces in China from 2017 to 2024. The results show that the sports industry and tourism industry have an increasing level of association, the trend of the coupling coordination degree evolving to a higher level, and the regional variability of the coupling coordination development mainly originates from inter-region, followed by intra-region, and the hypervariance density is small. In addition, the degree of coupled coordination of the two systems has a good σ convergence nature, the national and intra-regional coefficients of variation show an overall decline, local fluctuations in the trend of change, and there is a spatial absolute β convergence trend in the degree of coupled coordination of the two systems, the speed of convergence of the west>central>national>eastern. Accordingly, this paper puts forward corresponding policy recommendations, with a view to providing empirical reference and theoretical reference for realizing the common wealth of urban and rural areas.

Index Terms entropy weight TOPSIS method, coupling coordination, Kernel density estimation, Dagum Gini coefficient, sports industry, tourism industry

I. Introduction

China's deepening economic and social development has promoted the rapid change of industrial structure, and industrial integration has become the main expression of the current industrial structure [1], [2]. Industrial integration is a dynamic development process in which different industries penetrate into each other and eventually merge into one to form a new industry [3]. In the new social development environment, consumers' spiritual and cultural needs continue to improve, and industrial integration has become a development trend [4], [5]. And the mutual integration of sports industry and tourism industry is a new industrial model, the market, resources, technology and other factors promote the dynamic development of sports and tourism industry [6], [7].

The integrated development of sports tourism is an important direction of the current Chinese tourism industry and an important part of the Chinese sports industry [8]. Sports industry is a diversified industrial form integrating sports competition, sports industry and sports service, and tourism is a typical representative of experiential economy [9], [10]. The integrated development of sports tourism can drive the development of related industries, create more employment opportunities and promote economic growth [11]. The interaction between sports events and tourist attractions can improve the visibility and influence of the attractions and attract more tourists [12]. At the same time, sports tourism activities also require consumers to pay for tickets, accommodation and transportation, bringing more income to related industries [13], [14]. Of course, in the process of promoting the integrated development of sports tourism, it also faces some challenges and problems [15]. First, the integration of sports facilities and tourism resources needs to be further strengthened [16]. At present, although some tourist attractions in China have better tourism resources, they lack matching sports facilities [17]. Secondly, the organization and management of sports tourism activities need to be standardized and improved [18]. Due to the special nature of sports events, it is necessary to strengthen the security and management of the events to protect the personal safety and property safety of tourists [19], [20]. In the face of these problems, only by taking appropriate measures

to deal with them can we realize the coordinated development of the sports industry and tourism industry and improve the speed of economic development [21], [22].

Literature [23] utilized research methods such as literature method and observation method to outline the current research areas and deficiencies related to sports tourism, and proposed the development path of sports tourism in China based on the theory of experience economy. Literature [24] took the sports tourism industry in Yangshuo County as the research object, examined the development status quo, problems and countermeasures of the sports tourism industry by using the literature analysis method and the statistical analysis method, and emphasized that the current development of the sports tourism industry in Yangshuo needs to be carried out through the establishment of a complete scale system and the cultivation of talents in order to promote the development of the local tourism industry. Literature [25] constructed a user-oriented personalized tourism information recommendation model based on sports tourism big data, and discussed the development power mechanism and management mode of sports tourism by combining data mining knowledge and recommendation system algorithms, and the results showed that only the realization of sports tourism should be closely integrated with the sports industry, and a win-win situation can be achieved. Literature [26] introduced the sports tourism industry, pointed out its deficiencies, and examined the development of the sports tourism industry from the perspective of industrial integration by centering on the relevant concepts of the sports tourism industry and adopting effective processing measures. Literature [27] constructed an evaluation index system based on the panel data of nine provinces and regions in the Yellow River Basin, and measured the development indexes based on the entropy value method, the coupling coordination degree model and other methods, revealing that the overall growth level of the sports and tourism industries in the Yellow River Basin was on a continuous upward trend. Literature [28] took the coupling of Hunan tourism industry and sports industry as the research object, constructed the coupling degree and coordination degree model of sports and tourism industry, and the research results revealed that the coupling development mechanism of sports industry and tourism industry in Hunan Province was well developed, but the level was low, and there was a lot of space for development. Literature [29] based on field surveys, interviews and other research methods and based on the theory of synergy, examined the high-quality development path of rural sports tourism industry in Hainan, and elaborated a synergistic development path, i.e., to build a regional synergy in Hainan Province, the synergy of stakeholders, and the synergy of rural sports and tourism complex of the “trinity”. Literature [30] describes the current commercialization of sports tourism by the consumer group cognitive bias, insufficient product development innovation and other factors, and emphasizes the importance of formulating a reasonable development strategy, and puts forward the establishment of the official website of sports tourism, the establishment of online marketing platforms and other recommendations.

In this paper, panel data of 31 provinces (excluding Hong Kong, Macao and Taiwan) in mainland China from 2017 to 2024 are selected on the basis of existing studies, and the entropy method is used to measure the comprehensive scores of the development level of the sports industry and the tourism industry under the provincial perspective, and the coupling coordination degree of the two major systems is assessed by the coupling coordination model. In addition, Dagum Gini coefficient, Kernel density estimation and convergence model (including σ-convergence method and spatial β-convergence method) are comprehensively applied to analyze the temporal change, spatial evolution, regional difference and convergence characteristics of the coupled coordination degree of the two systems. Based on the results of these studies, a policy proposal is made for the synergistic development of the sports industry and tourism industry in the new era, in order to promote the harmonious coexistence of human and nature, and to promote the process of modernization and industrial construction.

II. Coupled and coordinated development model of sports and tourism industry development

II. A. Evaluation index system for the level of development of the sports and tourism industry

II. A. 1) Principles for the construction of the evaluation index system

(1) Principle of scientificity: the selection of indicators should not be a subjective decision, but should follow the pointing and representativeness of the indicators and be based on objective facts and scientific basis, in order to scientifically reflect the level and stage of the development of industrial integration. Moreover, the scientific principle should be carried out throughout the empirical research process, not only in the aspect of indicator selection, but also in the dimensionless processing of data, assignment of weights, and division of coupling level, etc. The scientific principle also needs to be strictly followed to ensure the authenticity of the research data results and the validity of the research conclusions.

(2) Systematic principle: Although sports industry and tourism industry belong to the category of tertiary industry service industry, and they have strong correlation, there are some differences and independence due to their different industrial functional attributes. Therefore, when selecting the indicators, it is necessary to make

comprehensive and integrated consideration of the indicators of each subsystem to ensure that the indicators of each subsystem can fully and systematically reflect the relevance and comprehensiveness of the subsystems, and then make the expression of the indicators more systematic, scientific and efficient, which lays a good foundation for the next step of the research.

(3) Principle of effectiveness: this paper takes the sports industry and tourism industry as the sub-systems, and the indicators of each system are complementary to each other, which not only reflects the meaning of the indicators themselves, but also reflects the cumulative effect between the indicators. The indicators will not change easily because of the change of the external environment, and have a long time stability. Each indicator can calculate the weight through the entropy value method, and use the coupling coordination model to find out the degree of coupling coordination and so on.

(4) Principle of representativeness: there are many indicators to measure the level of integrated development of sports and tourism, although the selection of indicators should be comprehensive and systematic, but comprehensive and systematic does not mean that it only focuses on the number, but also focuses on the representativeness of the indicators, and rejects the indicators that are duplicated in function and unrepresentative, which enables the constructed indicator system to accurately reflect the degree of integration of the development of sports and tourism, and the data obtained have a high degree of credibility. credibility.

(5) Principle of accessibility: Data related to the integrated development of the two industries can be obtained through statistical yearbooks, government agencies and field research. In order to ensure the smooth implementation of the work and the accuracy of the results, for some of the indicators that are difficult to obtain relevant data, alternative indicators that are easy to obtain data should be carefully selected and actively sought to ensure a smooth process and accurate results.

II. A. 2) Selection of evaluation indicators

This paper combines theory and practice, draws on the existing research results, refers to the national classification standards for sports and tourism industries, establishes a system of evaluation indicators for the development of the two industries in accordance with the principles of indicator construction, on the basis of ensuring the availability of data, taking into account the frequency of the appearance of each indicator, and combining the practice of integrated development of the sports and tourism industries with the opinions of experts in the relevant fields. Table 1 shows the indicators of the development level of sports and tourism industries. The guideline layer of sports industry includes financial input, industrial efficiency and market scale, and a total of 9 indicators are selected. The guideline layer of tourism industry includes industrial efficiency, industrial scale and industrial foundation, and a total of 11 indicators are selected. A total of 20 indicators are selected to reflect the level of development of the industry in a more intuitive way, in order to measure the degree of integration between the sports and tourism industries.

Table 1: Indicators of development of sports and tourism industries

Target layer	Criterion layer	Index layer	Attribute
Sports industry	Financial input	S1 Government appropriation	+
		S2 Cultural tourism sports and media spending	+
	Industrial benefit	S3 Sports revenue	+
		S4 Sports lottery sales	+
	Market size	S5 Frequent participation in physical activity	+
		S6 Per capita area	+
		S7 The number of workers in the sports department	+
		S8 A legal person engaged in a sports industry	+
		S9 Number of athletes	+
Tourism industry	Industrial benefit	T1 Travel revenue	+
		T2 Travel of travel agency	+
		T3 Operating income of star hotel	+
		T4 Inbound tourists spend every day in per capita	+
		T5 Added value of accommodation and catering	+
	Market size	T6 Visitors to the reception country	+
		T7 Visitors to the reception country	+
		T8 The number of residential and catering companies	+
		T9 The number of scenic spots	+
	Industrial basis	T10 Number of travel agents	+
		T11 The number of major star hotels	+

II. B.Methodology for calculating the level of comprehensive industrial development

II. B. 1) Data standardization

As the units of the indicators selected in this paper are different, including billion yuan, ten thousand yuan, ten thousand dollars, square meters, people, ten thousand people, individuals, percentages, etc., the original units and attributes of each data are not uniform, and it is impossible to calculate and compare them directly, so it is necessary to carry out the standardization of the original data in a dimensionless way to eliminate the influence of the indicators due to the differences in the attributes and units, and to improve the accuracy of the calculation results and the subsequent The accuracy of the calculation results and the reliability of the subsequent analysis can be improved. In this paper, we adopt the method of standardization of polar deviation to process the raw data, and use the standardized processing formula of positive indicators because all the indicators selected in this paper are positive indicators:

$$x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} + 0.001, \left(i = 1,2,\ldots,m, j = 1,2,\ldots,n\right) \tag{1}$$

where $i = 1,2,\cdots,n$ represents the order of years for each indicator, and $j = 1,2,\cdots,n$ represents the number of indicators. x_{ij} represents the raw data for indicator j in year i, and x'_{ij} represents its processed and normalized data. $\max x_j$ represents the maximum value of the j th indicator in the same year, and $\min x_j$ represents the minimum value of the indicator. In addition, 0.001 is added to the equation as a whole at the end to avoid zero values during processing.

II. B. 2) Determination of indicator weights

Entropy value method [31] is a method to determine the weight of each indicator in the system based on the calculation of the information entropy of each indicator, and its principle is to analyze the correlation and difference of each indicator through the original information of the data, and the greater the degree of variability of the value of a certain indicator within the system, the greater the value of the weight it possesses, and the greater the degree of influence it has on the system. Compared with other weight calculation methods, entropy value method is more objective and can determine the weight of each indicator more scientifically, avoiding the influence of subjective factors. Therefore, this paper utilizes the entropy value method to calculate the weights of indicators, and the steps and formulas are as follows:

(1) Calculate the weight of the value of Indicator j in year i as a percentage of the whole

Calculate the weight of indicator x'_{ij} P_{ij}:

$$P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}}, \left(i = 1,2,\ldots,m, j = 1,2,\ldots,n\right) \tag{2}$$

where, P_{ij} represents the weight of the j rd indicator in the i nd year after standardization, and x'_{ij} refers to the standardized value of the j th indicator in the i th year after dimensionless treatment.

(2) Entropy value calculation

Calculate the entropy value of the j th indicator e_j:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} P_{ij} \ln\left(P_{ij}\right) \tag{3}$$

The entropy value $e_j \geq 0$, P_{ij} is the weight of the j th indicator in the i rd year after standardization. When the difference in the value of an indicator in different years is larger, it means that it has a greater amount of information, a higher degree of importance, and a smaller entropy value.

(3) Calculation of coefficient of variation

$$g_j = 1 - e_j \tag{4}$$

The larger the coefficient of variation g_j is, the more important the indicator is, e_j is the entropy value of the j rd indicator, and the smaller the e_j is, the greater the impact of the indicator on the evaluation results.

(4) Determination of weights

Calculate the weight of each indicator w_j:

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{5}$$

where g_j is the coefficient of variation of the j nd indicator, the higher the value of the weight represents the higher importance of the indicator and the greater the impact on the evaluation results.

II. B. 3) Development of industry development level

After deriving the weight w_j of each indicator, the evaluation value of the comprehensive development level of the industry is calculated using the linear weighting method.

The evaluation value of the i nd year:

$$u_i = \sum_{j=1}^{m} w_j * P_{ij} \tag{6}$$

II. C.Model construction of coupling coordination degree between sports industry and tourism industry

Based on the commonality and relevance of the sports industry and tourism industry, the two have a close connection and good coupling conditions, with mutual penetration and mutual influence, thus forming the integration of the two industries. Therefore, on the basis of industrial integration theory and system coupling theory, this paper considers Fujian sports industry and tourism industry as two systems, and applies the coupling coordination degree model to measure and analyze the degree of integration and the integration state of China's sports industry and tourism industry.

II. C. 1) Calculation of coupling

Coupling C:

$$C = 2\sqrt{\frac{u_1 u_2}{(u_1 + u_2)^2}} \tag{7}$$

where $C \in (0,1)$, represents the coupling degree of sports industry and tourism industry, and the larger value of C indicates the deeper degree of integration. u_1 and u_2 are the evaluation values of the comprehensive development level of sports industry and tourism industry calculated above, respectively.

II. C. 2) Calculation of the degree of coupling coordination

Degree of coupling coordination D:

$$D = \sqrt{C \times T} \tag{8}$$

Composite harmonization index T:

$$T = \alpha u_1 + \beta u_2 \tag{9}$$

Among them, $D \in (0,1)$, represents the coupling and coordination degree of sports industry and tourism industry [32], the larger the value of D indicates that the coupling and coordination degree of the two is better, T is the comprehensive coordination index of the two, α and β are the contribution degree of sports industry and tourism industry in the integrated development of the two as well as in the socio-economic development, respectively, and $\alpha + \beta = 1$, with reference to the research results of other scholars, it is considered that the two are of equal importance here, and therefore $\alpha = \beta = 0.5$ is taken.

In order to assess the degree of coupling coordination, the degree of coupling coordination of sports tourism industry is divided into 10 levels with reference to Liao Chongbin's “ten points method”. Table 2 shows the coupling degree of coordination of the level of standardized score.

Table 2: Coupling coordination scale classification

Coupling coordination	Coordination level	Coupling coordination	Coordination level
0~0.09	Extreme dissonance	0.50~0.59	Grudging
0.10~0.19	Severe disorder	0.60~0.69	Primary coordination
0.20~0.29	Moderate disorder	0.70~0.79	Intermediate coordination

0.30~0.39	Mild disorder	0.80~0.89	Good coordination
0.40~0.49	On the brink	0.90~1.00	Quality coordination

II. D.Methods of spatial analysis

II. D. 1) Dagum Gini coefficient

Compared with traditional methods such as the Gini coefficient and the Terrell index, the Dagum Gini coefficient decomposition method can effectively solve the problem of cross overlap between subsamples and decompose spatial variance into intra-regional variance, inter-regional variance, and hypervariance density, so as to obtain more rigorous and precise measurement results. Therefore, this study adopts the Dagum Gini coefficient decomposition method to study spatial differences and their sources [33]. Let G denote the overall Gini coefficient, and the larger G is, the larger the overall gap between the coupled coordination degree of the two systems is, and its expression is shown as follows:

$$G=\frac{\sum_{j=1}^{k}\sum_{l=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_l}\left|y_{ji}-y_{lr}\right|}{2n^2\bar{y}} \tag{10}$$

where n represents the number of cities, k represents the total number of regions, n_j and n_l represent the number of cities in regions j and l, respectively, y_{ji} and y_{lr} represent the coupling coordination degree of any city in regions j and l, respectively, and $\bar{y}$ is the average value of the coupling coordination degree of the two systems.

Based on this method, the Gini coefficient is decomposed into the contribution of intra-regional variation G_w, the contribution of inter-regional variation G_{nb}, and the contribution of hypervariance density G_t, where G_w is the difference in the distribution of coupling harmonization within a region j or l, G_{nb} is the difference in the distribution of coupling harmonization between a region j and a region l, and G_t is the effect of the presence of the cross term of inter-regional coupling harmonization on the overall variation in the division of the subgroups, and the relationship between these three is 0 in case of the absence of the cross term. hypervariable density contribution is 0. There is $G=G_w+G_{nb}+G_t$ a relationship between the three.

II. D. 2) Kernel density estimation

The formula for Kernel density estimation [34] is shown below:

$$f(x)=\frac{1}{Nh}\sum_{i=1}^{N}K\left(\frac{X_i-x}{h}\right) \tag{11}$$

where X_i is the observation of the i nd sample, x is the mean, N is the number of observations, h is the bandwidth, and $k(\cdot)$ is the Gaussian kernel function, which is selected in this study to estimate the dynamic evolution of coupled coordination, and its expression is shown below:

$$K(x)=\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{x^2}{2}\right) \tag{12}$$

In order to fully grasp the evolutionary characteristics of the coupled coordination degree distribution pattern, the spatial kernel density estimation incorporates spatio-temporal factors on the basis of the traditional kernel density estimation to estimate the probability density of the random variable as follows:

$$g(y\mid x)=\frac{f(x,y)}{f(x)} \tag{13}$$

$$f(x,y)=\frac{1}{Nh_xh_y}\sum_{i=1}^{N}K_x\left(\frac{X_i-x}{h_x}\right)K_y\left(\frac{Y_i-x}{h_y}\right) \tag{14}$$

where $g(y\mid x)$ denotes the kernel density under spatial conditions, $f(x)$ denotes the marginal kernel density function for x, and $f(x,y)$ denotes the joint kernel density function for x and y.

II. D. 3) Convergence model

Common convergence models are σ convergence and β convergence. σ Convergence refers to the tendency of the deviation of the coupling coordination degree of each city to decrease with the advancement of time, and this study adopts the coefficient of variation to measure the σ convergence, and the calculation formula is as follows:

$$\sigma = \frac{\sqrt{\sum_{i=1}^{N_j}(D_{ij} - \bar{D}_{ij})^2 / N_j}}{\bar{D}_{ij}} \tag{15}$$

where D_{ij} denotes the degree of coupling coordination of i cities in the region j, $\bar{D}_{ij}$ denotes the mean value of coupling coordination of cities in the region j, and N_j denotes the number of cities in the region j.

β Convergence refers to the fact that as time progresses, the city with lower coupling coordination has a higher rate of increase to catch up with the city with higher coupling coordination, and the gap between the two gradually narrows and eventually reaches the same steady state level. β Convergence can be divided into absolute β convergence and conditional β convergence. Absolute β convergence refers to a series of factors that do not take into account the important impact on the degree of coordination of coupling, the degree of coordination of coupling between cities has a tendency to converge. Absolute β convergence is modeled as follows:

$$\ln\frac{D_{i,t+1}}{D_{i,t}} = \alpha + \beta \ln D_{i,t} + \mu_i + \eta_t + \varepsilon_{i,t} \tag{16}$$

where $D_{i,t+1}$ indicates the coupling coordination degree of the i nd city in the $t+1$ rd period, $D_{i,t}$ indicates the coupling coordination degree of the i th city in the t th period, $\ln\frac{D_{i,t+1}}{D_{i,t}}$ indicates the growth rate of the coupling coordination degree of the i th city in the $t+1$ th period, β is the convergence coefficient, $\beta<0$ indicates that the coupling coordination degree of the city has a tendency to converge, and vice versa there is a tendency to diverge, and the speed of convergence is $v = -\ln(1-|\beta|)/T$ (T indicates the time period), μ_i, η_t, and $\varepsilon_{i,t}$ indicate the area effect, time effect, and random perturbation term, respectively.

Considering the obvious spatial correlation characteristics of urban coupling coordination degree, this study introduces the spatial panel model to carry out the research. Common spatial measurement models include spatial lag model (SAR), spatial error model (SEM), spatial Durbin model (SDM), etc., of which the SDM model can be regarded as a general form of the SAR model and SEM model. The spatial absolute β convergence models of the three models are as follows:

SAR model:

$$\ln\frac{D_{i,t+1}}{D_{i,t}} = \alpha + \beta \ln D_{i,t} + \rho\sum_{j=1}^{n} w_{ij} \ln\frac{D_{j,t+1}}{D_{j,t}} + \mu_i + \eta_t + \varepsilon_{i,t} \tag{17}$$

SEM modeling:

$$\ln\frac{D_{i,t+1}}{D_{i,t}} = \alpha + \beta \ln D_{i,t} + \mu_i + \eta_t + \lambda\sum_{j=1}^{n} w_{ij}\mu_{j,t} + \varepsilon_{i,t} \tag{18}$$

SDM model:

$$\begin{aligned}\ln\frac{D_{i,t+1}}{D_{i,t}} = {} & \alpha + \beta \ln D_{i,t} + \rho\sum_{j=1}^{n} w_{ij} \ln\frac{D_{j,t+1}}{D_{j,t}} \\ & +\gamma\sum_{j=1}^{n} w_{ij} \ln D_{j,t} + \mu_i + \eta_t + \varepsilon_{i,t}\end{aligned} \tag{19}$$

where ρ is the spatial lag coefficient, indicating the influence of the growth rate of the coupling coordination degree of neighboring cities' physical tourism industry development on the coupling coordination degree of this city, λ is

the spatial error coefficient, indicating the existence of spatial effects in the random perturbation term, γ is the spatial lag coefficient of the independent variable, indicating the influence of the coupling coordination degree of the neighboring cities, and w is set to be the spatial weighting matrix constituted by the inverse of the square of the geographic distance as an element.

Condition β convergence model adds a series of control variables on the basis of absolute β convergence model, aiming at exploring whether there is a convergence trend of urban coupling coordination degree in each region under a series of important influencing factors on urban coupling coordination degree. The conditional β convergence model is as follows:

Ordinary panel model:

$$\ln\frac{D_{i,t+1}}{D_{i,t}}=\alpha+\beta\ln D_{i,t}+\delta X_{i,t}+\mu_i+\eta_t+\varepsilon_{i,t} \tag{20}$$

SAR modeling:

$$\ln\frac{D_{i,t+1}}{D_{i,t}}=\alpha+\beta\ln D_{i,t}+\delta X_{i,t}+\rho\sum_{j=1}^{n}w_{ij}\ln\frac{D_{j,t+1}}{D_{j,t}}+\mu_i+\eta_t+\varepsilon_{i,t} \tag{21}$$

SEM modeling:

$$\ln\frac{D_{i,t+1}}{D_{i,t}}=\alpha+\beta\ln D_{i,t}+\delta X_{i,t}+\mu_i+\eta_t+\gamma\sum_{j=1}^{n}w_{ij}\mu_{j,t}+\varepsilon_{i,t} \tag{22}$$

SDM model:

$$\begin{aligned}\ln\frac{D_{i,t+1}}{D_{i,t}}=&\alpha+\beta\ln D_{i,t}+\delta X_{i,t}+\rho\sum_{j=1}^{n}w_{ij}\ln\frac{D_{j,t+1}}{D_{j,t}}\\&+\gamma\sum_{j=1}^{n}w_{ij}\ln D_{j,t}+\mu_i+\eta_t+\varepsilon_{i,t}\end{aligned} \tag{23}$$

where $X_{i,t}$ represents the many control variables affecting the degree of urban coupling coordination, and δ is a vector of parameters.

III. Results and analysis

Considering the accuracy and availability of the data, this study adopts the panel data of two industries in 31 provinces in China (excluding Hong Kong, Macao and Taiwan) from 2017-2024 as the object of analysis, and the data are mainly obtained from the China Statistical Yearbook, China Tourism Statistical Yearbook, the website of the Ministry of Finance of China, the website of the General Administration of Sport of the State Council, and the announcement of the sports meetings in each province and city, and some of the missing data are supplemented and improved by interpolation.

III. A. Analysis of the level of coupled and coordinated development of the sports industry and tourism industry

III. A. 1) Indicator weights

According to equation (5), the weights of the indicators for evaluating the level of development of the sports and tourism industry can be calculated, and Table 3 shows the results of the weights of the indicators.

Table 3: The result of the index weight

Target layer	Criterion layer	Index layer	Weight
Sports industry	Financial input	S1 Government appropriation	0.111
		S2 Cultural tourism sports and media spending	0.111
	Industrial benefit	S3 Sports revenue	0.111
		S4 Sports lottery sales	0.111
	Market size	S5 Frequent participation in physical activity	0.111
		S6 Per capita area	0.111

		S7 The number of workers in the sports department	0.111
		S8 A legal person engaged in a sports industry	0.111
		S9 Number of athletes	0.111
Tourism industry	Industrial benefit	T1 Travel revenue	0.1279
		T2 Travel of travel agency	0.0975
		T3 Operating income of star hotel	0.0683
		T4 Inbound tourists spend every day in per capita	0.0908
		T5 Added value of accommodation and catering	0.0928
	Market size	T6 Visitors to the reception country	0.0971
		T7 Visitors to the reception country	0.1304
		T8 The number of residential and catering companies	0.074
		T9 The number of scenic spots	0.0774
	Industrial basis	T10 Number of travel agents	0.0929
		T11 The number of major star hotels	0.0519

III. A. 2) Comprehensive level of development

According to the results of entropy method, Table 4 and Table 5 show the results of measuring the development level of China's sports industry and tourism industry respectively, and the development of China's sports industry and tourism industry presents the following characteristics:

(1) Overall, the development level of the sports industry and tourism industry is on the rise (except for 2024), with an average annual growth rate of more than 10%, which belongs to the sports industry's development over the top type. Further analysis found that the difference between the comprehensive development level of the two industries was 0.0016 in 2017, but the difference was gradually pulled after 2018, originating from the fact that the state issued the “Opinions on Accelerating the Development of the Sports Industry and Promoting Sports Consumption” and other relevant policies in 2018, which created a good development environment for the sports industry through institutional innovation, cultivation of diversified main bodies, and improvement of industrial layout.

(2) From the provincial perspective, 20 provinces, including Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Anhui, Zhejiang, Fujian, Shandong, Henan, Hubei, Guangdong, Guangxi, Hainan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang, are ahead of the development of the sports industry. Beijing, Tianjin, Shanxi, Shanghai, Jiangxi, Hunan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet 11 provinces for tourism industry development ahead of the type. As for the sports industry, Jiangsu (0.350) and Guangdong (0.320) push forward the construction of a strong sports province and rank in the top two in terms of the level of development, while Tibet, although it has a better momentum in the development of mountaineering, the sports industry as a whole needs to be further developed, and the score is in the tail position. As for the tourism industry, Shanghai (0.544) and Beijing (0.350) are economic and political centers respectively, with diversified tourism consumer markets and development levels in the top two, while Qinghai and Ningxia, despite having special scenic spots such as the Qinghai Lake and Shapotou, are confined to geographic remoteness, weak economies and backward facilities, which limit their ability to attract tourists, and their scores are in the bottom two.

(3) The sports industry and tourism industry in some provinces and cities are at a high level of development, most prominent in coastal areas and first-tier cities. Comparing the rankings of the sports industry and tourism industry development level and the total GDP of 31 provinces in China in 2017 and 2024, it can be seen that Guangdong, Jiangsu, Shandong, Zhejiang, etc., which are ranked in the top of the total GDP, have the same high development level of the sports industry and tourism industry. It can be seen that the level of regional economic development is an important endogenous driving force for the development of sports industry and tourism industry, and the economic growth can upgrade the consumption mode of the residents, expand the consumption market, and help the industry to develop with high quality.

(4) Except for 2020 (affected by the epidemic), the level of development of the tourism industry in each province is relatively stable, while the fluctuation of the sports industry is more obvious, with eight and six provinces showing a decline in 2019 and 2020, respectively. It is presumed to be influenced by the internal environment of some regions of China that have implemented policies to reduce investment in sports fixed assets in recent years, coupled with the external environment of the slowdown in the world economy in 2019, the development of the sports industry in some provinces has seen a reverse growth.

Table 4: Comprehensive development level score and list of sports industry

Province	Province								Rank
	2017	2018	2019	2020	2021	2022	2023	2024	2017~2024
Jiangsu	0.247	0.35	0.367	0.412	0.498	0.49	0.555	0.350	1
Guangdong	0.291	0.281	0.307	0.327	0.388	0.435	0.458	0.320	2
Beijing	0.242	0.27	0.247	0.309	0.281	0.357	0.353	0.265	3
Shandong	0.158	0.215	0.228	0.239	0.354	0.352	0.37	0.274	4
Zhejiang	0.164	0.161	0.205	0.221	0.249	0.361	0.363	0.243	5
Fujian	0.156	0.187	0.219	0.224	0.247	0.296	0.387	0.245	6
Shanghai	0.172	0.195	0.199	0.27	0.281	0.281	0.273	0.16	7
Shaanxi	0.154	0.155	0.18	0.188	0.209	0.27	0.285	0.251	8
Henan	0.124	0.182	0.172	0.204	0.205	0.281	0.298	0.23	9
Hebei	0.13	0.17	0.176	0.183	0.191	0.227	0.267	0.157	10
Hubei	0.13	0.156	0.143	0.179	0.191	0.247	0.256	0.19	11
Liaoning	0.149	0.12	0.162	0.167	0.179	0.187	0.222	0.119	12
Anhui	0.118	0.159	0.149	0.134	0.147	0.185	0.216	0.155	13
Sichuan	0.071	0.105	0.109	0.119	0.141	0.173	0.222	0.18	14
Gansu	0.066	0.108	0.141	0.132	0.155	0.169	0.146	0.141	15
Hainan	0.105	0.129	0.119	0.119	0.137	0.135	0.143	0.145	16
Yunnan	0.058	0.059	0.115	0.152	0.156	0.176	0.172	0.138	17
Jiangxi	0.074	0.082	0.092	0.125	0.141	0.166	0.187	0.149	18
Xinjiang	0.056	0.091	0.09	0.139	0.141	0.164	0.166	0.165	19
Shanxi	0.105	0.122	0.186	0.104	0.121	0.139	0.15	0.1	20
Hunan	0.096	0.115	0.135	0.111	0.117	0.167	0.165	0.098	21
Tianjin	0.095	0.088	0.112	0.118	0.113	0.121	0.119	0.127	22
Guizhou	0.099	0.101	0.09	0.111	0.117	0.115	0.121	0.126	23
Inner Mongolia	0.105	0.095	0.092	0.108	0.129	0.123	0.127	0.095	24
Qinghai	0.054	0.076	0.141	0.103	0.108	0.12	0.115	0.129	25
Guangxi	0.054	0.063	0.076	0.129	0.115	0.14	0.159	0.101	26
Heilongjiang	0.095	0.127	0.078	0.109	0.123	0.111	0.104	0.083	27
Jilin	0.059	0.075	0.087	0.077	0.163	0.11	0.155	0.081	28
Ningxia	0.058	0.056	0.061	0.077	0.103	0.088	0.139	0.111	29
Chongqing	0.047	0.048	0.055	0.074	0.086	0.09	0.115	0.055	30
Tibet	0.018	0.023	0.025	0.026	0.032	0.038	0.039	0.049	31

Table 5: The tourism industry comprehensive development level score and the list

Province	Province								Rank
	2017	2018	2019	2020	2021	2022	2023	2024	2017~2024
Shanghai	0.501	0.495	0.519	0.54	0.565	0.575	0.58	0.544	1
Beijing	0.374	0.377	0.394	0.369	0.393	0.387	0.447	0.35	2
Jiangsu	0.211	0.22	0.232	0.273	0.284	0.295	0.308	0.218	3
Guangdong	0.244	0.257	0.272	0.229	0.243	0.263	0.284	0.166	4
Zhejiang	0.197	0.21	0.218	0.195	0.258	0.273	0.289	0.225	5
Shandong	0.166	0.18	0.204	0.221	0.232	0.256	0.266	0.184	6
Yunnan	0.092	0.1	0.11	0.136	0.174	0.231	0.358	0.157	7
Guizhou	0.091	0.097	0.106	0.144	0.187	0.244	0.3	0.155	8
Tianjin	0.137	0.147	0.152	0.165	0.168	0.186	0.183	0.13	9
Anhui	0.117	0.12	0.137	0.146	0.167	0.188	0.219	0.137	10
Hunan	0.095	0.099	0.119	0.135	0.168	0.197	0.207	0.189	11
Sichuan	0.103	0.113	0.129	0.145	0.183	0.179	0.198	0.126	12
Henan	0.104	0.114	0.129	0.143	0.158	0.185	0.212	0.125	13
Hupei	0.124	0.131	0.132	0.153	0.153	0.166	0.167	0.121	14
Guangxi	0.076	0.085	0.094	0.116	0.145	0.183	0.238	0.17	15

Jiangxi	0.071	0.093	0.114	0.135	0.15	0.185	0.214	0.142	16
Fujian	0.09	0.098	0.107	0.125	0.135	0.165	0.184	0.134	17
Shanxi	0.092	0.094	0.114	0.136	0.152	0.173	0.199	0.091	18
Liaoning	0.093	0.1	0.106	0.127	0.144	0.149	0.173	0.103	19
Hebei	0.079	0.089	0.097	0.115	0.14	0.162	0.192	0.102	20
Chongqing	0.097	0.098	0.104	0.111	0.121	0.152	0.177	0.132	21
Shaanxi	0.079	0.087	0.105	0.119	0.13	0.153	0.178	0.087	22
Jilin	0.047	0.049	0.064	0.073	0.081	0.099	0.119	0.07	23
Hainan	0.055	0.059	0.055	0.055	0.059	0.067	0.076	0.061	24
Kansu	0.026	0.032	0.042	0.055	0.069	0.078	0.101	0.059	25
Inner Mongolia	0.032	0.032	0.047	0.053	0.065	0.077	0.086	0.053	26
Heilongjiang	0.033	0.037	0.044	0.043	0.055	0.054	0.072	0.043	27
Tibet	0.031	0.031	0.045	0.04	0.039	0.046	0.048	0.031	28
Xinjiang	0.017	0.014	0.023	0.036	0.041	0.05	0.075	0.03	29
Qinghai	0.017	0.006	0.012	0.022	0.028	0.032	0.046	0.02	30
Ningxia	0.009	0.017	0.015	0.019	0.023	0.019	0.028	0.023	31

III. A. 3) Spatial and temporal evolution of coupling coordination degree

The coupling coordination degree of China's sports industry and tourism industry is calculated through the coupling coordination model, and Figure 1 shows the distribution of the coupling coordination degree of the sports industry and tourism industry under the provincial perspective. Horizontal coordinates 1~31 are Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Anhui, Zhejiang, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

Overall, the degree of coupled coordination of the two industries evolves from the severe dislocation stage in 2017 (0.180) to the moderate dislocation stage in 2024 (0.225). Considering the severe impact of the epidemic on the service industry in 2020, excluding the re-observation results in 2020, it is found that the coupling and coordination relationship between the two industries is still in the moderate dysfunctional stage, but it is very close to the mild dysfunctional, reflecting that the epidemic has a serious impact on the coupling relationship between the two industries, and also indicating that the two industries are showing a tendency for the level of correlation to continue to increase and the degree of coupling and coordination to evolve to a higher level.

From the relationship between the coupling coordination degree and the comprehensive development level of the industry, the provinces with higher coupling coordination rank such as Beijing, Zhejiang, Jiangsu, etc. also rank in the forefront of the development level of the sports and tourism industries, while the provinces with lower rank such as Ningxia, Tibet, etc. are relatively backward in the development level of the two industries. This is due to the fact that the sports industry and tourism industry have a certain development interaction: on the one hand, sports events, landmark stadiums (museums), ethnic folk sports performances, etc. have become important tourism attractions to meet the needs of tourists, shape the image of tourism, and enhance the attractiveness of scenic spots. On the other hand, the combination of natural resources, humanistic landscape and sports can enhance tourism attraction. For example, the Qingming Shangheyuan in Kaifeng, Henan Province, combines natural landscapes with rock-climbing and water competitions, giving tourism a new form of expression and further enhancing the competitiveness of the tourist resort.

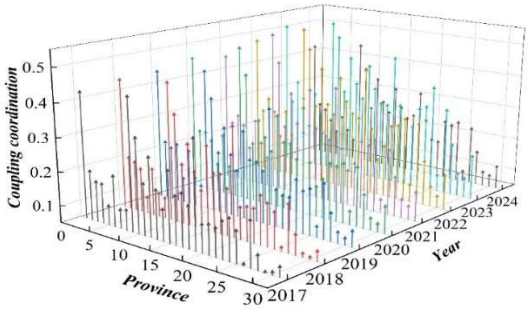


Figure 1: China sports industry and tourism industry coupling coordination score

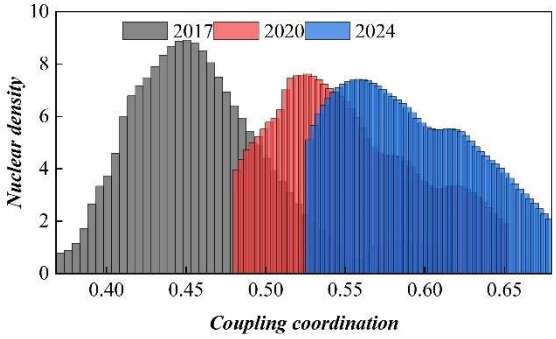
III. B. Kernel Density Analysis of Coupling Coordination Degree

The Kernel density estimation method is used to depict the distribution location, shape, ductility and polarization of the kernel density curve of the coupling coordination degree in China and the 4 major regions, and then analyze the dynamic evolution trajectory of the coupling coordination degree. The main trends of the kernel density curves of coupling coordination degree in 2017, 2020 and 2024 are presented, and Figure 2 shows the evolution trend of the kernel density curves of coupling coordination degree in China and the 4 major regions, with (a) to (e) showing the kernel density curves of China, the east, the center, the west and the northeast, respectively.

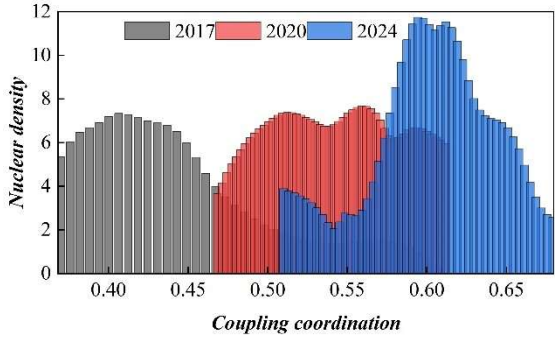
At the Chinese level, the kernel density curve shows the evolutionary characteristics of “gradually shifting to the right, with the peak declining faster and then slower, the width narrowing, and the trailing phenomenon gradually becoming less significant”. Among them, the curve of kernel density is constantly shifting to the right, indicating that the level of coordinated development of rural revitalization coupled with common prosperity continues to increase, and there is a tendency to develop to a higher stage. The peak value decreases and the bandwidth narrows, indicating that there is a clustering phenomenon in the coupling coordination degree of each region, that is, the gap between the coupling coordinated development level of the inter-region is constantly narrowing, and there is a coordinated development trend. 2017 kernel density curve appeared in the form of a “double-peak”, and the form of “double-peak” gradually weakened after the years 2020 and 2024. The pattern of “double peaks” gradually weakened and changed to “single peaks”, indicating that the phenomenon of bipolarization or multipolarization gradually disappeared with the passage of time, with the trend of balanced development, and the phenomenon of trailing tail gradually became insignificant, proving that the phenomenon of strong nuclei between regions is not obvious.

At the regional level, in the eastern region, the kernel density curve is characterized by a gradual shift to the right, with the peak increasing slowly and then rapidly, the width narrowing rapidly and the trailing phenomenon not significant. Among them, the Kernel Density Curve keeps shifting to the right as time passes, indicating that the level of coupled and coordinated development in the eastern region is constantly improving and has a good and sustainable development trend. In the central region, the kernel density curves show the evolution characteristics of “gradually shifting to the right, the peak value first rapidly decreasing and then slowly increasing, the width first rapidly spreading and then slowly narrowing, and the trailing phenomenon is not significant”. Among them, the kernel density curve gradually shifts to the right, indicating that there is an increasing trend in the coupling coordination degree in the central region. In the western region, the kernel density curve shows the evolutionary characteristics of “gradually shifting to the right, the speed of peak enhancement is first fast and then slow, the width narrowing speed is also first fast and then slow, and the trailing phenomenon is not significant”. Among them, the kernel density curve keeps moving to the right, indicating that the level of coupled and coordinated development in the western region is constantly improving, and there is also a transition from “single peak - double peak”, indicating that there is a more obvious gradient effect, and the polarization phenomenon is relatively obvious, but there is no highly concentrated area. In the northeast region, the nuclear density curve shows the evolution characteristics of “gradually shifting to the right, with the peak value rapidly rising and then rapidly falling, the width narrowing and then spreading, and the trailing phenomenon is not significant”. Among them, the density curve keeps shifting to the right, indicating that the coupling coordination development level in the northeast region also has a continuous upward trend.

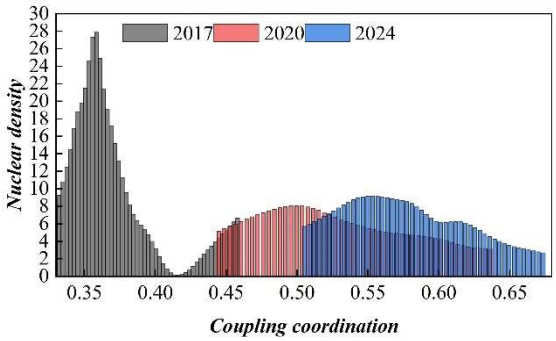
In conclusion, the level of coupled and coordinated development in China and the four regions shows an increasing trend, and the differences between regions are gradually narrowing, and there is a trend of coordinated development.



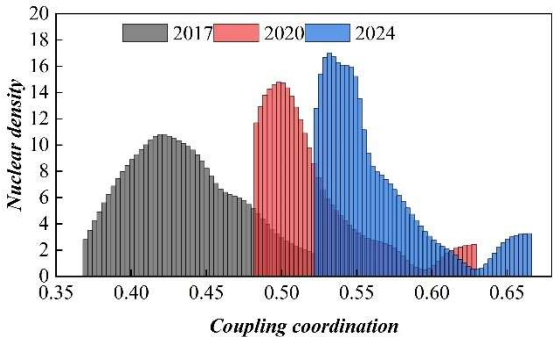
(a) Whole country



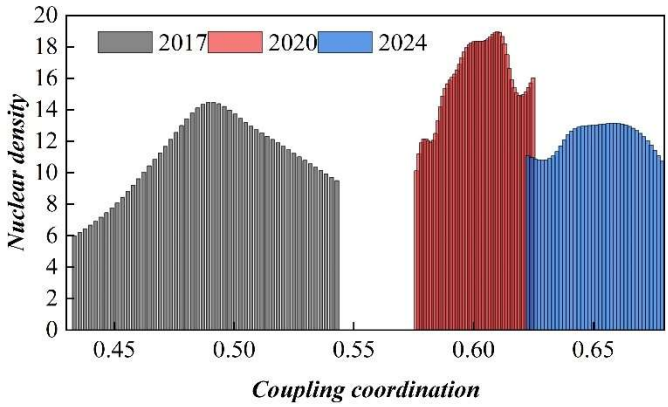
(b) East



(c) Middle



(d) West



(e) Northeast

Figure 2: Nuclear density curve

III. C. Regional Variability and Sources of Coupling Harmonization Degree

The Dagum Gini coefficient method is applied to provide a detailed decomposition of the coupled coordination degrees of China and the 4 major regions in order to reveal their spatial variability and causes, Table 6 shows the results of Gini coefficients within (between) the 4 major regions from 2017-2024, and Table 7 shows the results of the source decomposition of the Gini coefficients of China as a whole, with the East, Central, West and Northeast denoted by E, M, W and N.

Table 6: The Gini coefficient of the area (between)

Year	E	M	W	N	E-M	E-W	E-N	M-W	M-N	W-N
2017	0.040	0.043	0.047	0.016	0.049	0.077	0.047	0.071	0.042	0.045
2018	0.033	0.044	0.047	0.015	0.046	0.068	0.044	0.061	0.036	0.045
2019	0.032	0.046	0.043	0.019	0.037	0.068	0.038	0.062	0.036	0.048
2020	0.036	0.039	0.037	0.014	0.043	0.067	0.037	0.063	0.033	0.043
2021	0.037	0.043	0.040	0.017	0.044	0.063	0.041	0.056	0.030	0.040
2022	0.036	0.038	0.039	0.007	0.038	0.065	0.031	0.055	0.031	0.040
2023	0.034	0.035	0.039	0.020	0.040	0.057	0.043	0.054	0.034	0.033
2024	0.035	0.042	0.029	0.017	0.037	0.059	0.042	0.056	0.034	0.035
Mean	0.035	0.041	0.040	0.016	0.042	0.066	0.040	0.06	0.035	0.041

Table 7: The source of the coefficient of the Gini coefficient in China

Year	Gini	Regional difference		Regional gap		Supervariable density	
		Contribution value	Contribution rate/%	Value	Rate/%	Value	Rate/%
2017	0.057	0.012	21.43	0.032	56.96	0.012	21.61
2018	0.051	0.012	23.28	0.028	55.29	0.011	21.43
2019	0.049	0.011	22.77	0.028	56.55	0.01	20.68
2020	0.048	0.011	22.03	0.027	57.23	0.01	20.74
2021	0.047	0.011	22.6	0.026	54.68	0.011	22.72
2022	0.046	0.011	22.92	0.024	53.17	0.011	23.91
2023	0.045	0.01	22.64	0.024	53.43	0.011	23.93
2024	0.044	0.01	21.95	0.024	55.27	0.01	22.78
Mean	0.048	0.011	22.92	0.027	56.25	0.01	20.83

III. C. 1) Overall and intra-regional variations in the degree of coupling harmonization

As can be seen from Table 6, in terms of intra-regional differences, the mean values of the Gini coefficient in the four major regions of China are, in descending order, Central (0.041) > Western (0.040) > Eastern (0.035) > Northeastern (0.016). Overall, compared to the initial value in 2017, the Gini coefficients of China, the East, the West and the Northeast, except for the Central region, show a decreasing trend. For this reason, the strategy of coordinated regional development should be continuously promoted, and efforts should be made to narrow the gap between regions and promote coordinated regional development.

As can be seen from Table 7, the overall Gini coefficient mainly fluctuates within the range of the interval [0.044, 0.057], and except for a small increase in the phenomenon in 2017-2018, it generally shows a decreasing trend year by year, indicating that there is a continuous weakening of the regional variability in the degree of coupling coordination in China as a whole.

III. C. 2) Inter-regional differences in the degree of coupling coordination

In terms of inter-regional disparities, the mean values of the Gini coefficients between regions, in descending order, are as follows: East-West (0.066)>Central-West (0.060)>East-Central (0.042)>West-North-East (0.041)>East-North-East (0.040)>Central-North-East (0.035). It can be seen that, in general, the difference in the level of coupled and coordinated development between the eastern region and the rest of the regions is greater than the gap between the non-eastern regions. At the same time, the imbalance between the west and the east and central regions is particularly prominent. Among them, the Gini coefficient in the East-Central region shows a decreasing trend, the East-West region is in an overall decreasing trend except for the phenomenon of an increase in 2017-2018, and the number of upward and downward fluctuations of the Gini coefficient among the remaining regions is more frequent. Overall, the Gini coefficients of the remaining regions, except for the central-western and central-northeastern regions, all showed a downward trend compared with the initial value in 2017, indicating that there is a widening of the gap in the level of coupled and coordinated development between the central, northeastern, and western regions, and so it is necessary to make efforts to address the problem of unbalanced interregional development.

III. C. 3) Sources of regional variability and contribution to the degree of coupling coordination

A detailed decomposition of the overall Gini coefficient is carried out in order to clearly reveal the causes of regional variability in the degree of coupled coordination. As can be seen from Table 7, the overall Gini coefficient is mainly derived from the inter-regional disparity contribution rate, followed by the intra-regional disparity contribution rate, and the hypervariable density contribution rate is low. In addition, compared with the initial contribution rate in 2017, both the intra-regional disparity contribution rate and the inter-regional disparity contribution rate show a small downward trend, and only the hypervariable density contribution rate shows an upward trend, but the overall fluctuation is small and relatively stable, indicating that the inter-regional imbalance is still dominant, and the inter-regional variability should not be underestimated.

III. D. Convergence analysis of the coupling coordination degree of the sports and tourism industry

III. D. 1) Analysis of σ-convergence

Calculating the dynamic change of the coefficient of variation of the coupling coordination degree of the whole country and the three regions, Figure 3 shows the σ-convergence analysis of the coupling coordination degree of the sports and tourism industry. From the evolution trend, the coefficient of variation at the national level has experienced a process of “obvious decline first and then leveling off”, with an overall decreasing trend during the

observation period. The variation trend of the coefficient of variation in the eastern region is basically consistent with that of the whole country, i.e., a rapid decline followed by a gradual stabilization, while the coefficient of variation in the central region shows a sharp decline followed by small fluctuations, with an overall slow downward trend. The coefficient of variation in the western region is similar to that in the central region, with a rapid decline followed by slight fluctuations, and a slow decline throughout the observation period. Taken together, the coefficient of variation has small fluctuations locally but shows a slow downward trend overall, showing a better σ-convergence nature, which is consistent with the results obtained from the previous analysis using the Dagum Gini coefficient, i.e., the national as well as the internal differences of the three regions have a clear trend of narrowing during the observation period.

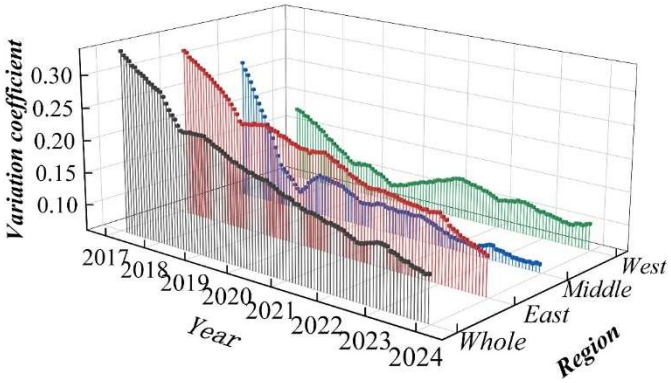


Figure 3: The variation coefficient of the coupling coordination of the two systems

III. D. 2) β-convergence

In terms of model selection, LM, LR, and Wald tests were conducted for the whole country and the three regions, respectively. The results show that the two-way fixed SDM model is the most suitable model. Table 8 shows the estimation results of two-way fixed SDM model, from which it can be seen that the β coefficients of the whole country and the three regions are significantly negative, which means that there is spatial absolute β convergence in the degree of coupling and coordination of the sports industry and tourism industry, i.e., there is a "club" effect between the regions, and the provinces with a lower degree of coupling and coordination will converge to the provinces with a higher degree of coupling and coordination. In addition, the speed of convergence of each region is observed. In addition, observing the convergence speed and half-life cycle of each region, it is found that the western region has the fastest convergence speed, 0.042, and the half-life cycle is 17.112 years, which indicates that it takes the shortest time for the western region provinces and cities with lower degree of coupling and coordination to catch up with the provinces and cities with higher degree of coupling and coordination of the two systems. The convergence speed of the central region is the second fastest, 0.038, and the half-life cycle is 17.685 years. Subsequently, the national convergence rate of 0.022, half-life cycle of 26.851 years, the eastern region of the slowest convergence rate of 0.018, half-life cycle of only 35.228 years, the convergence rate of the west > central > national > eastern.

Table 8: Two way fixed SDM model estimation results

Variable	Whole country	East	Middle	West
β	-0.333*** (0.035)	-0.238*** (0.066)	-0.444*** (0.058)	-0.453*** (0.071)
Convergence	Yes	Yes	Yes	Yes
v	0.022	0.018	0.038	0.042
τ (year)	26.851	35.338	17.685	17.112
Log_L	565.582	277.028	151.332	212.223
R^2	0.401	0.599	0.633	0.333
N	450	165	130	155

IV. Conclusions and recommendations

IV. A. Conclusion

Using panel data of 31 provinces in mainland China from 2007 to 2024, this study constructs a comprehensive evaluation index system for the development of sports industry and tourism industry by entropy value method, and analyzes the spatio-temporal evolution characteristics, spatial variability, spatial agglomeration and convergence characteristics of their coupled and coordinated development by combining the methods of the coupled and coordinated model, Dagum's Gini coefficient, the coefficient of variation and the spatial Durbin model. The results show that:

(1) Overall, the development level of the sports industry and tourism industry is on the rise (except for 2024), with an average annual growth rate of more than 10%, which belongs to the development of the sports industry ahead of its time. The coupling and coordination relationship between the two industries is still in the stage of moderate dislocation, but it is very close to the mild dislocation, which indicates that the two industries are in the trend of increasing the level of association and evolving the degree of coupling and coordination to a higher level.

(2) The overall Gini coefficient shows a decreasing trend year by year, and the mean value of the Gini coefficient within the region decreases in accordance with the central, western, eastern, and northeastern regions, which indicates that the variability of the coupling coordination degree is larger in the central region, followed by the western and eastern regions, and smaller in the northeastern region Regional variability mainly comes from the inter-regional, followed by the intra-regional, and the hypervariance density is smaller.

(3) From the point of view of convergence characteristics, the degree of coupled coordination of the two systems has a good σ convergence nature, the national and intra-regional coefficients of variation show an overall decline, local fluctuations in the trend of change, and there is a spatial absolute β convergence trend in the degree of coupled coordination of the two systems, with the speed of convergence West>Central>National>Eastern.

IV. B. Recommendations

IV. B. 1) Enhancing the comprehensive development of the industry

(1) Vigorously promoting sports tourism consumption. In some key regions and cities across the country, new sports tourism consumption scenarios have been created, new sports tourism consumption modes have been cultivated, and efforts have been made to stimulate the public's sports tourism consumption demand from both the supply side and the demand side.

(2) Gradually improve the special supporting service system for sports tourism facilities. On the one hand, support localities to speed up the construction progress of sports tourism facilities such as national fitness centers, sports parks, fitness trails, and public service facilities for outdoor sports. On the other hand, it taps into historical culture and fashion elements to create high-quality sports tourism events, routes and brands, and realizes the high-quality integration and synergistic development of the two.

(3) Promote green and healthy lifestyles. Encourage the public to participate in various outdoor sports such as hiking, camping, mountaineering, skiing, cycling, road running, etc., and support various sports social organizations to descend into the community to organize sports tourism activities for the general public, so as to further explore the consumption potential of sports tourism, green travel and other areas.

IV. B. 2) Playing a leading role in areas with integration advantages

(1) Give full play to the leading demonstration role of provinces with higher levels of integration and development of the sports and tourism industries, and drive the development of sports tourism in neighboring regions. Strengthen the synergy and cooperation between inter-regional and intra-regional sports industry and tourism industry, promote the free, orderly and efficient flow and optimal allocation of the elements of the two industries of sports and tourism in the inter-region and intra-region, and better promote the synergistic development of sports and tourism in the developed regions in the east and the less-developed regions in the west and northeast of China.

(2) Establish and improve the inter-regional benefit compensation mechanism. For the differences in the development of sports tourism caused by personnel mobility and capital transfer, diversified compensation methods such as tax sharing and ecological compensation should be actively explored, so as to ensure that in the process of the integrated development of the sports industry and the tourism industry, the regions can equitably share the fruits of development.

IV. B. 3) Multiple measures to address shortcomings

(1) The development of the sports industry. First, to enrich the supply of sports consumption, we should continue to make up for the short board of sports venues and facilities, and implement the “short board” project of national fitness venues and facilities. The second is to expand and strengthen the sports program industry and build a complete sports program industry chain. The third is to innovate and develop new sports products, promote the

construction of new sports space, create new scenes of sports consumption, and create a number of sports service complexes with distinctive regional characteristics, perfect service functions and good economic benefits, so as to enhance the economic benefits of the sports industry and thus improve the contribution rate of the sports industry.

(2) Tourism industry development level. First, it is necessary to continuously improve tourism facilities, raise the level of tourism services, better base on the unique tourism resources of each region, pay attention to discovering and integrating the connotation of local tourism culture, and develop a series of diversified, personalized and innovative tourism products. Secondly, it is necessary to accelerate technological change, promote the “tourism +” model, better promote the extensive application of digital technology in sports scenes, provide consumers with a better tourism experience, and thus better enhance the economic benefits of the tourism industry.

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