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# Empirical Research and Optimization Paths of Jiangsu Water Sports Industry Chain Development from a Synergistic Perspective

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**Abstract:** Based on the synergy theory, this study divides the Jiangsu water sports industry chain into three subsystems: the upstream equipment R&D and manufacturing subsystem, the midstream event operation and training subsystem, and the downstream cultural and tourism integration and consumption subsystem. A synergy evaluation system including 12 indicators is constructed, and the composite system coordination degree model and entropy weight method are used to empirically measure the synergy level of Jiangsu's water sports industry chain in 2024. The results show that the overall synergy degree of Jiangsu's water sports industry chain is 0.38, which is in a state of near imbalance. The order degrees of the three subsystems present the characteristics of "slightly higher midstream, lower upstream and downstream", and the 13 prefecture-level cities form an obvious "core-periphery" gradient pattern. There is a "negative locking" mechanism in the industrial chain, including upstream technical shortcomings, midstream administrative dependence, and downstream homogeneous competition, and unbalanced regional development has become an important restrictive factor. Accordingly, this study proposes collaborative optimization paths from four dimensions: technological breakthrough, event marketization, downstream differentiated development, and cross-departmental governance, providing empirical basis and practical reference for promoting the high-quality development of Jiangsu's water sports industry.

**Keywords:** synergy theory; water sports industry; industry chain; synergy degree; composite system coordination degree model

## 1. Introduction

The water sports industry is an important format of in-depth integration of the sports industry with cultural tourism, manufacturing and other industries. Its high-quality development is of great significance for promoting the upgrading of the sports industry and advancing the coordinated development of the regional economy [1]. As the only province in China that has large rivers, large lakes and the sea at the same time, Jiangsu has unique water resource endowments and has initially formed a complete water sports industry chain system covering equipment R&D and manufacturing, venue construction, event organization, and cultural tourism integration. However, in the process of development, problems such as the core technology of the upstream industrial chain being controlled by others, insufficient market-oriented operation in the midstream, serious homogenization in the downstream, and unbalanced regional development between southern and northern Jiangsu have become prominent, and the synergistic effect of various links in the industrial chain has not been effectively played. The synergy theory provides a scientific framework for analyzing the interactive relationship between various subsystems within the industrial system, and its core emphasizes that the system achieves evolution from disorder to order through the cooperation between subsystems, thereby improving the overall function. In recent years, domestic scholars have applied

the synergy theory to sports industry research, but there is still a lack of quantitative synergy measurement research on the water sports industry chain. Based on this, from a synergistic perspective, this study constructs a synergy evaluation index system for the water sports industry chain, clarifies the current situation of collaborative development and restrictive factors of Jiangsu's water sports industry chain through empirical measurement, and puts forward targeted optimization paths, in order to provide theoretical support and practical guidance for solving the collaborative dilemma of the industrial chain and promoting the high-quality development of Jiangsu's water sports industry.

## 2. Core concepts and theoretical basis

### 2.1. Core concepts

#### 2.1.1. Water sports industry chain

Taking water resources as the carrier, it is a complete industrial system covering upstream equipment R&D and manufacturing, venue construction, midstream event operation and education and training, and downstream cultural and tourism integration and brand marketing [2]. Each link forms an interrelated and mutually supportive value creation network through the flow of materials, information and funds [3].

#### 2.1.2. Industrial chain synergy degree

It reflects the order degree of the internal development of each subsystem of the industrial chain and the matching, coordination and linkage level between subsystems. It is an important index to measure the overall development efficiency of the industrial chain. The higher the synergy degree, the higher the resource allocation efficiency and overall competitiveness of the industrial chain [3].

### 2.2. Theoretical basis

Synergy theory, proposed by German physicist Hermann Haken, is suitable for analyzing the evolution law of open complex systems. Its core includes synergy effect, enslavement principle and self-organization principle [4]. The synergy effect refers to the effect that the overall function produced by the cooperation between subsystems is greater than the sum of each part; The enslavement principle emphasizes that the order parameter is the key slow variable governing the system evolution, which determines the development direction of the system; The self-organization principle indicates that the system can form an ordered structure through the interaction of internal elements without external mandatory instructions. Applying synergy theory to the research of water sports industrial chain, the industrial chain can be regarded as a complex open system composed of upstream, midstream and downstream subsystems. By measuring the order degree of each subsystem and the overall synergy degree of the system, we can identify the key bottlenecks (lack of order parameters) in the system evolution, reveal the interaction mechanism between subsystems, and provide a theoretical basis for promoting the collaborative development of the industrial chain. The composite system coordination degree model is an important quantitative tool of synergy theory, which can objectively measure the synergy level of the industrial chain by calculating the order degree of subsystems and the overall coordination degree of the system, providing method support for the empirical analysis of this study.

### 2.3. Research on sports industrial chain

Foreign research on sports industrial chain is based on theories such as value chain and global production network [5], exploring the division of labor, cooperation and governance mode of the industrial chain, and emphasizing the role of factor flow and technological cooperation in promoting industrial synergy. Domestic research mostly focuses on specific fields such as ice and snow sports and event industry [6], constructing an evaluation index system for industrial chain synergy, and conducting empirical measurement by using methods such as coupling coordination degree and grey correlation analysis. However, the research on the synergy of water sports industrial chain

is still in the exploration stage [7], and a systematic quantitative analysis framework has not yet been formed, and the research on the spatial differentiation of the industrial chain within the province is relatively lacking.

*2.4. Research review*

Existing research has laid a foundation for the research on the synergy of water sports industrial chain, but there are still two deficiencies: first, in terms of research methods, there are more qualitative studies and fewer quantitative studies on measuring the synergy level of the industrial chain, and there is a lack of exclusive evaluation system for the water sports industrial chain; second, in terms of research perspective, most studies focus on a single link of the industrial chain or the macro regional level, and the analysis of the interaction mechanism of each link of the industrial chain within the province and the characteristics of spatial differentiation is insufficient. In view of the above deficiencies, this study constructs a synergy evaluation index system of Jiangsu water sports industrial chain and carries out quantitative empirical research to fill the relevant research gaps.

## 3. Empirical measurement of the synergy degree of Jiangsu water sports industrial chain

*3.1. Research design*

### 3.1.1. Subsystem division

Combined with the composition characteristics of the water sports industrial chain, it is divided into three subsystems: upstream equipment R&D and manufacturing subsystem (S1), covering equipment R&D, patent transformation, key equipment localization and other links; midstream event operation and training subsystem (S2), including event holding, commercial operation, education and training and other links; downstream cultural and tourism integration and consumption subsystem (S3), involving water sports tourism, derivative development, regional coordination and other links.

### 3.1.2. Index system construction

Following the principles of systematicness, scientificity and operability, through literature review and two rounds of Delphi expert consultation, a synergy evaluation index system including 12 indicators is constructed. Among them, the upstream subsystem selects 4 indicators: R&D investment intensity, number of patent authorizations, patent conversion rate and key equipment localization rate; the midstream subsystem selects 4 indicators: total number of events held annually, proportion of commercial event income, government subsidy dependence and proportion of sports training enterprise revenue; the downstream subsystem selects 4 indicators: water sports tourism income, tourist satisfaction of cultural and tourism projects, proportion of derivative sales income and regional coordination index (Table 1).

**Table 1.** Evaluation indicators of the synergy degree of Jiangsu water sports industrial chain

| Subsystem | Indicator layer |
| --- | --- |
| Upstream subsystem (S1) | R&D investment intensity |
| | Number of patent authorizations |
| | Patent conversion rate |
| | Key equipment localization rate |
| Midstream subsystem (S2) | Total number of events held annually |
| | Proportion of commercial event income |
| | Government subsidy dependence |
| | Proportion of sports training enterprise revenue |
| Downstream subsystem (S3) | Water sports tourism income |
| | Tourist satisfaction of cultural and tourism projects |

Proportion of derivative sales income

Regional coordination index

### 3.1.3. Weight determination

The entropy weight method is used to determine the index weight. This method conducts objective weight assignment based on the degree of data dispersion, which effectively avoids the interference of subjective factors. The results show that the patent conversion rate (0.20) has the highest weight in the upstream subsystem, the government subsidy dependence (0.22) has the highest weight in the midstream subsystem, and the proportion of derivative sales income (0.20) has the highest weight in the downstream subsystem. The distribution of each index weight is highly consistent with the actual pain points of the development of Jiangsu water sports industry.

### 3.1.4. Model selection

The composite system coordination degree model is used to measure the industrial chain synergy degree. First, the order degree of each subsystem is calculated, and then the deviation penalty term is introduced to calculate the overall synergy degree. The formulas are as follows:

Order degree of subsystem:

$$U_{ij} = \frac{X_{ij} - \alpha_{ij}}{\beta_{ij} - \alpha_{ij}}$$

Overall synergy degree:

$$U_j = \sum_{i=1}^{m} \omega_{ij} U_{ij} \ (j = 1,2,3)$$

Among them, $\theta$ is the deviation coefficient, which is the key penalty term of the model, used to reflect the balance degree of the development between subsystems. The value range of synergy degree C is [0,1]. Referring to relevant studies, the synergy level is divided into: low synergy (C<0.4), medium synergy (0.4≤C<0.6), high synergy (C≥0.7), among which C<0.4 is the state of near imbalance.

### 3.1.5. Data sources and processing

The data are from "Jiangsu Statistical Yearbook 2024", "Jiangsu Sports Industry Development Statistical Communique 2024", government data of Jiangsu Provincial Sports Bureau and Department of Culture and Tourism, on-site enterprise survey data and authoritative industry reports. The data are standardized and tested for reliability and validity to ensure the reliability and comparability of the data.

### 3.2. Empirical results and analysis

### 3.2.1. Analysis of subsystem order degree

In 2024, the order degrees of the three subsystems of Jiangsu water sports industrial chain are all at the medium-low level, among which the midstream subsystem has the highest order degree (0.52), the downstream subsystem is the second (0.45), and the upstream subsystem is the lowest (0.43), showing the characteristics of "slightly higher midstream, lower upstream and downstream" (Table 2).

**Table 2.** Calculation results of the order degree of each subsystem of Jiangsu water sports industrial chain in 2024

| Subsystem | Order degree | Synergy level | Key restrictive factors |
|---|---|---|---|
| Upstream subsystem (S1) | 0.43 | Medium synergy (low) | Patent conversion rate (0.32), key equipment localization rate (0.29) |

| | | | |
|---|---|---|---|
| Midstream subsystem (S2) | 0.52 | Medium synergy | Government subsidy dependence (0.41), proportion of commercial event income (0.48) |
| Downstream subsystem (S3) | 0.45 | Medium synergy (low) | Homogenization rate of cultural and tourism projects (reverse index, 0.38), proportion of derivative sales income (0.40) |

The core reason for the low order degree of the upstream subsystem is the double low of patent conversion rate (0.32) and key equipment localization rate (0.29). Most of the domestic equipment manufacturing enterprises in the province are concentrated in the middle and low-end market. Key equipment such as high-performance composite material hulls and intelligent navigation systems rely on imports, and the transformation of innovative achievements is not smooth, forming a "technological island", which has become the core short board for the upgrading of the industrial chain. Although the order degree of the midstream subsystem is relatively high, its internal structure is unbalanced, with high dependence on government subsidies (0.41) and low proportion of commercial event income (0.48). Most events rely on government funding support, and the cultivation of independent IP events is lagging behind, failing to play the value transmission role of the industrial chain hub. Downstream subsystem: restricted by the high homogenization rate of cultural and tourism projects (0.38) and low proportion of derivative sales income (0.40), there is a huge development gap between southern and northern Jiangsu. High-quality water resources have not been effectively converted into industrial efficiency, the regional coordination mechanism is lacking, and the value-added capacity is insufficient.

3.2.2. Analysis of overall synergy degree

In 2024, the overall synergy degree of Jiangsu water sports industrial chain is 0.38, which is in the low synergy interval, belonging to the state of near imbalance. This indicates that the matching and linkage level between each subsystem of the industrial chain is low, the resource allocation efficiency is not high, and the synergy effect of "1+1+1>3" has not been effectively played. The core reason lies in the unbalanced development between subsystems and low deviation coefficient. The upstream technical short board increases the midstream operation cost, the midstream administrative dependence weakens the market signal, and the downstream homogeneous competition inhibits the value release. The three restrict each other, forming a vicious circle of "negative locking".

3.2.3. Analysis of spatial differentiation characteristics

By decomposing the industrial chain synergy degree of 13 prefecture-level cities in Jiangsu Province, the results show that the synergy degree of each city presents an obvious "core-periphery" gradient pattern [8] (Table 3).

**Table 3.** Synergy degree and spatial differentiation of water sports industrial chain in 13 prefecture-level cities of Jiangsu Province

| Echelon | City | Region | Synergy degree (C) | Comparison with the provincial average | Spatial characteristics |
|---|---|---|---|---|---|
| First echelon | Suzhou | Southern Jiangsu | 0.51 | +34.2% | Core leading area: A local collaborative network has been initially formed, but it |

| | | | | | faces the bottleneck of high-end breakthrough. |
|---|---|---|---|---|---|
| | Nanjing | Southern Jiangsu | 0.48 | +26.3% | |
| | Wuxi | Southern Jiangsu | 0.45 | +18.4% | |
| Second echelon | Changzhou | Southern Jiangsu | 0.41 | +7.9% | Transitional support area: It has a certain foundation, but the collaborative structure is fragile and vulnerable to impact. |
| | Zhenjiang | Southern Jiangsu | 0.38 | ±0% | |
| | Yangzhou | Central Jiangsu | 0.36 | -5.3% | |
| | Nantong | Central Jiangsu | 0.34 | -10.5% | |
| | Taizhou | Central Jiangsu | 0.33 | -13.2% | |
| Third echelon | Yancheng | Northern Jiangsu | 0.3 | -21.1% | Peripheral lag area: There is a serious mismatch between resource endowment and industrial efficiency, and the foundation for system synergy is weak. |
| | Huai'an | Northern Jiangsu | 0.28 | -26.3% | |
| | Xuzhou | Northern Jiangsu | 0.27 | -28.9% | |
| | Lianyungang | Northern Jiangsu | 0.26 | -31.6% | |
| | Suqian | Northern Jiangsu | 0.24 | -36.8% | |

Core leading area: Suzhou (0.51), Nanjing (0.48), Wuxi (0.45), all located in southern Jiangsu. Relying on a solid economic foundation, improved infrastructure and a large consumer market, a local closed loop of "resources-events-consumption" has been initially formed, but there are problems such as insufficient high-end technological breakthroughs and limited influence of independent IP. - Transitional support area: Changzhou (0.41), Zhenjiang (0.38), Yangzhou (0.36), Nantong (0.34), Taizhou (0.33), covering some cities in southern Jiangsu and all cities in central Jiangsu. The development level is close to or slightly lower than the provincial average, which is prone to low-level homogeneous

competition and fragile collaborative structure. - Peripheral lag area: Yancheng (0.30), Huai'an (0.28), Xuzhou (0.27), Lianyungang (0.26), Suqian (0.24), the five cities in northern Jiangsu. Although they have high-quality water resources, due to backward infrastructure, lack of professional talents and low market brand awareness, the resources have not been effectively converted into industrial advantages, and there is a huge gap with the core area.

## 4. Collaborative optimization path of Jiangsu water sports industrial chain

Based on the empirical research results, aiming at the problems of low synergy degree, unbalanced subsystem development and obvious regional differentiation of Jiangsu water sports industrial chain, combined with synergy theory and industrial development reality, this paper puts forward collaborative optimization paths from four dimensions: technological breakthrough, event marketization, downstream differentiation and cross-departmental governance, breaking the "negative locking" mechanism and promoting the industrial chain to evolve in an orderly and collaborative direction. (1) Take upstream technological breakthrough as the breakthrough point to break the "low-end locking" and "technological island" Focus on the core short board of the upstream subsystem and build a market-oriented industry-university-research collaborative innovation system [9]. Led by the provincial level, establish the "Jiangsu Water Sports Equipment Collaborative Innovation Center", establish a demand collection and release mechanism, connect the midstream event operation and downstream consumption demand, guide universities, scientific research institutes and manufacturing enterprises to carry out joint technological research, and focus on breaking through the core technological bottlenecks such as high-performance boats, intelligent navigation systems and safety equipment [10]. Set up a provincial risk compensation fund for the application of the first (set) of equipment, provide subsidies to units using key equipment independently developed in the province, and promote the transformation of innovative achievements. Cultivate a number of leading equipment manufacturing enterprises with independent intellectual property rights, improve the localization rate of key equipment, and lay a solid technological foundation for the collaborative development of the industrial chain. (2) Take midstream event IPization and operation marketization as the engine to reverse the inertia of "administrative dependence" Promote the transformation of midstream event operation from "administrative leading" to "market leading", and give play to the value transmission role of its midstream hub. The government changes its role from an event "organizer" to a "planner" and "incubator", accurately supports independent event IP with regional cultural characteristics, such as the Grand Canal Rowing Marathon and Taihu Lake Sailing Tour, and creates a "one city, one product" event pattern. Introduce professional market-oriented operation subjects, clarify the property rights of event IP, encourage operation subjects to expand diversified income channels such as sponsorship, media copyright and licensed products, and reduce the dependence on government subsidies. Strengthen the integration of events and education and training [11], expand the number of water sports participants, cultivate a stable consumer market, promote the midstream link to form a market-oriented operation mode of "self-hematopoiesis", transmit high-end technological demand to the upstream, and output high-quality content products to the downstream. (3) Take downstream differentiated development and regional coordination as the carrier to realize value increment and spatial balance Based on the differences in resource endowments of southern, central and northern Jiangsu, promote the differentiated development of downstream links and build a cross-regional coordination mechanism. Relying on the advantages of science and technology and consumption, southern Jiangsu will focus on developing high-end water sports experience, intelligent cultural tourism, industrial exhibitions and other formats to create a benchmark for high-quality development; central Jiangsu will give play to its location advantages [12], undertake the industrial spillover from southern Jiangsu, and develop event supporting, mass leisure water sports and other formats; northern Jiangsu will rely on ecological water resources, focus on cultivating the integrated format of

"water sports + ecological tourism + rural health care", develop characteristic products such as natural research and wetland exploration, and avoid homogeneous competition [13]. Led by the provincial cultural and tourism and sports departments, compile an integrated development plan for water sports tourism, design cross-city "one trip, multiple stops" high-quality routes, implement mutual recognition of regional service standards and resource sharing, create a unified "Water Rhythm Jiangsu" water sports brand, and realize functional complementarity and value increment between regions. (4) Take cross-departmental governance and data empowerment as the foundation to consolidate the institutional foundation for collaborative development Break the "fragmented" management system and build a modern industrial governance system to provide institutional guarantee for the collaborative development of the industrial chain. Establish the "Joint Meeting System of Jiangsu Water Sports Industry Development Departments" to coordinate sports, cultural and tourism, industry and information technology, natural resources, finance and other departments, regularly consult and solve cross-departmental problems such as water area opening, land use guarantee, safety supervision and fund guidance, and form a policy synergy. Build the "Jiangsu Water Sports Industry Big Data Platform", collect key data of each link of the industrial chain, realize data sharing and real-time monitoring, accurately grasp consumption trends and industrial operation status through big data analysis [14], provide a scientific basis for industrial collaborative decision-making, and promote the transformation of industrial chain collaborative development from "experience governance" to "scientific governance".

## 5. Conclusion

Based on the synergy theory, this study divides the Jiangsu water sports industrial chain into three subsystems: upstream equipment R&D and manufacturing, midstream event operation and training, and downstream cultural and tourism integration and consumption, constructs a synergy evaluation system including 12 indicators, and uses the composite system coordination degree model and entropy weight method to empirically measure the synergy level of the Jiangsu water sports industrial chain in 2024. The results show that the overall synergy degree of Jiangsu water sports industrial chain is 0.38, which is in the state of near imbalance. The order degrees of the three subsystems present the characteristics of "slightly higher midstream, lower upstream and downstream". The "negative locking" mechanism of upstream technical short board, midstream administrative dependence and downstream homogeneous competition exists in the industrial chain, and the unbalanced regional development has become an important restrictive factor. In order to promote the collaborative development of Jiangsu water sports industrial chain, it is necessary to make efforts from four dimensions: technological breakthrough, event marketization, downstream differentiated development and cross-departmental governance, build an industry-university-research collaborative innovation system, cultivate market-oriented event IP, promote regional differentiated development and resource integration, improve the cross-departmental governance and data empowerment system, break the "negative locking" mechanism, improve the order degree and overall synergy degree of each subsystem of the industrial chain, and realize the optimal allocation of resources and value increment of the industrial chain. The empirical results and optimization paths of this study provide a reference for the high-quality development of Jiangsu water sports industry, and also provide a reference for the collaborative development of water sports industrial chain in other regions with rich water resources in China. This study still has certain limitations. It carries out static analysis based on the cross-sectional data of 2024, and fails to reveal the dynamic evolution process of industrial chain synergy. In the future, panel data can be collected to carry out longitudinal time series analysis, and system dynamics and other methods can be combined to simulate the evolution trend of industrial chain synergy under different policy interventions, so as to further enrich the research conclusions.

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