International Journal for Housing Science and Its Applications
Publish August 10, 2025. Volume 46, Issue 4 Pages 3247-3259

https://doi.org/10.70517/ijhsa464459a

The role of spatial development dynamics of sports economy in the framework of evolutionary game theory in promoting regional economic growth

Ruikai Chen[1,2] and Shuiquan Wang[3,*]
[1] SANMING University, Sports & Health College, Sanming, Fujian, 365004, China
[2] College of Physical Education and Health Sciences, Zhejiang Normal University, Jinhua, Zhejiang, 321004, China
Corresponding authors: (e-mail: chenruikai9988@163.com).

Abstract A systematic, scientific and comprehensive understanding of the sports industry will better guide and promote the sustainable and healthy development of the sports industry. In this paper, under the perspective of evolutionary economics, the spatial development power mechanism and evolutionary trend of regional sports economy are studied. The evolutionary game theory is used to construct a sports economic growth pole model, which explains the reasons for the emergence of regional sports economy, the influencing factors and its spatial agglomeration effect. The dynamic relationship between the operation and development of the sports industry and the regional economic growth is discussed, and numerical simulation is carried out on the constructed model, and the measures and methods for the market regulation of the sports economy under different market sizes are given through the stability analysis under different oscillatory conditions. The simulation results show that the regional economic growth system, after a period of policy adjustment, will converge near the equilibrium point $E(x_1^*=0.063, x_2^*=1.287, x_3^*=0.119)$. And this point is the stable growth path of the sports economy development and regional economic growth system.

Index Terms evolutionary game, sports economy, growth pole model, spatial aggregation effect, market adjustment

I. Introduction

In recent years, the rapid development of the regional economy has benefited from the increasingly visible status quo of the economic development of the sports industry. The development of the sports industry is becoming more and more diversified, the consumption and investment in the sports industry is becoming more and more important in economic development, and the correlation between regional economic growth and the economic development of the sports industry is becoming stronger and stronger.

Sports industry is a comprehensive economic sector that provides society with tangible sports products or intangible sports services of economic activities [1], [2]. From the point of view of spatial economic theory, the sports industry can not be separated from the premise of spatial constraints for the production of various economic activities, and the smooth operation of any economic activity is carried out in a specific space [3], [4]. Space is not only a prerequisite for the operation of economic activities, but also exists in the whole process of economic activities in the form of a production factor [5]-[7]. Regional economic activities operate in a suitable spatial scope, which is conducive to the generation of scale effects and technological spillover effects, and the ability of collaboration between enterprises is enhanced [8], [9]. When the sports industry is highly concentrated in a specific geographic area, the industrial capital elements continue to converge in the spatial scope, which will eventually form industrial focus and promote the rapid development of the local sports industry [10]-[12]. Therefore, studying the spatial development power mechanism of the sports economy and realizing the sports industry agglomeration area with wide coverage and high level of development are conducive to promoting the transformation of the industrial structure in the region and enhancing the economic growth level in the region [13], [14].

Li, J. et al. showed that high-quality sports industry promotes economic growth, and researched the factors affecting the development of sports industry by solving the constructed model between different variables and the value added of sports industry[15].Dong, B. established a dynamic model for the high-quality development of the sports industry in the environment of the digital economy and constructed the evaluation system of the high-quality development of sports with the aim of reforming the sports industry by reforming its structural layout in order to improve the quality of the sports industry [16].Chen, J. et al. used exploratory spatial data analysis method and spatio-temporal correlation analysis method to study the spatio-temporal evolution process and future development trend of the sports industry in China, and the results showed that the spatial and regional differences of the sports

industry in China are significant, and there are obvious spatial agglomeration phenomenon and spatial spillover effect [17].Luo, M. et al. believed that the residents' Health is a key indicator of economic growth and social progress, so they measured the degree of agglomeration of different regions of China's sports industry and analyzed its spatial spillover effect on the health level of the residents by using the spatial Durbin model [18]. Xu, J. et al. found that the degree of concentration of the sports industry has a significant impact on the regional green economic growth, although there is a significant difference in the degree of influence between different regions, but the overall performance of the “green” effect is not significant. But the overall performance of the “inverted u-type” relationship, that is, within a certain degree of high concentration of the sports industry to promote the development of regional green economy [19].

The main innovation of this paper is that, in the traditional network evolutionary game research framework, the two-way matching process based on information dissemination before the game is introduced, and it is applied to the study of the spatial development of the sports economy power mechanism, and its impact on regional economic growth. Using the evolutionary game model for system modeling, a systematic simulation combining qualitative and quantitative can be carried out on the operating system of the sports industry. By observing the operation characteristics of the sports industry and regional economic growth system, we can grasp the operation mechanism and law of the system, reflect the operation state of the system through the change of different parameters, and determine the way to make the system realize the reasonable operation on the basis of this. By studying the operation characteristics of the sports industry system, the development trend of the system can be predicted, thus providing a strong basis for the government and sports enterprises to make decisions.

II. Theoretical foundations

II. A. Total Life Cycle Cost Theory

II. A. 1) Life cycle of the sports industry

The full life cycle of an industry is the overall process of an industry from generation to extinction, including a series of processes of strategic planning, planning, design, construction, use and adaptive reuse (or recycling). The concept of cost in economics refers to the resources consumed by people to carry out production and business activities. The whole life cycle cost of an industry refers to the resources consumed in the whole process from the beginning of the strategic planning of an industry to the reuse, including human resources, material resources, environmental resources and so on.

The relationship between cost and time is shown in Figure 1, where the increase of life cycle cost in the pre-construction and design periods of the sports industry gradually becomes larger, while the possibility of being affected gradually decreases. When entering the construction period, the cost increase is the largest, and after the industry is established, the cost increase decreases, but the cumulative amount gradually increases with time.

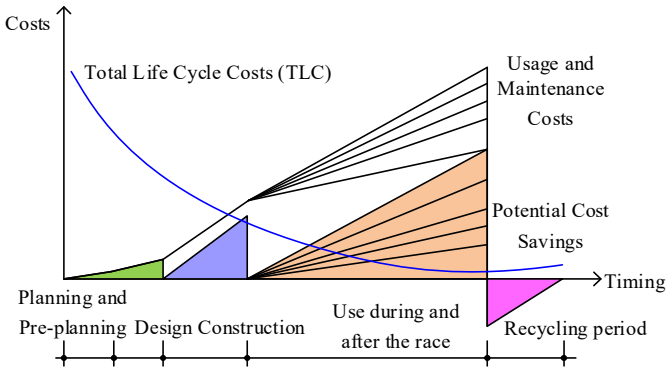


Figure 1: Change Trend of Life Cycle cost of Sports Venues

II. A. 2) Sports Industry Costing

At present, the feasibility study of the industry uses investment estimation to estimate the cost of the construction project, on the basis of which it is studied whether the project is to be built or not. The investment estimation requires a certain degree of accuracy, and once approved in general shall not be arbitrarily broken. The content of the investment estimate includes the project engineering costs, other costs, engineering reserve costs and loan interest during the construction period. The industrial planning stage can draw on the calculation method of investment estimation for the investment in the construction period, and should also pay attention to the calculation of the utilization cost from the perspective of the whole life cycle.

The construction scale of sports industry is the most important issue in the estimation, and there exists a reasonable scale for every project, and the so-called reasonable scale is the concept of “moderation”. The reasonable scale under the realistic conditions is the best program selected after the comparison of multiple programs. The selection of the best construction scale, there can be net present value index method, linear programming method.

(1) Net present value index method

This method is to take the scale corresponding to the program with the largest net present value index as the selected reasonable economic scale when comparing multiple programs.

The first step is to estimate the total investment of different scales according to certain expansion indexes, which is calculated by the formula:

$$K = k \cdot Q + K' \tag{1}$$

where K is the total project investment. k for the expansion of indicators, that is, unit product investment. Q for the production scale, K' for the total amount of other investment (generally refers to the external conditions of investment or special investment).

The second step, according to the cost level under different scales, respectively estimate the annual net cash inflow after the commissioning of each program.

The third step, according to a certain expected rate of return on investment, respectively, the construction period cash outflow and production period net cash inflow of each program discounted to the present value.

Step 4: Calculate the present value ratio of each scenario E_j:

$$E_j = \frac{\sum_{t=1}^{N} (P_1)_{jt}}{\sum_{t=1}^{n} (P_0)_{jt}} \tag{2}$$

where E_j is the present value ratio of the j nd program, N is the project production period, $(P_1)_{jt}$ is the present value of net cash inflows in the t th year of the j th program, $(P_0)_{jt}$ is the present value of net cash outflows in the t th year of the j th program, and n is the project infrastructure period.

(2) Linear Programming Method

General use of linear programming method preferred moderate, reasonable economic scale of the mathematical model for:

$$Z_{\max} = \sum_{j=1}^{n} E_j x_j \left(j = 1, 2, 3, \cdots, n \right) \tag{3}$$

$$\sum_{j=1}^{n} a_{ij} x_j \le B_i \left(0 \le x_j \le R_j \right) \tag{4}$$

In this case, Z is the objective function, which means that the profit is maximized, and similarly the cost is minimized (i.e., $Z_{\min}$). n for the number of product categories, E_j for the j th product unit profit (or unit cost). x_j is the scale of production of the j th product (usually expressed in terms of annual production), a_{ij} is the amount of the i th resource consumed per unit of the j th product ($j = 1, 2, 3, \cdots, m$. m is the total number of resources). B_i is the total amount of the j th resource, and R_j is the market demand of the j th product.

By applying the above two methods it is possible to compare the options for the reasonable size of the sports industry.

II. B.Evolutionary game theory

II. B. 1) Classical game theory

The traditional Prisoner's Dilemma game is often used to study the evolution of cooperative strategies. It assumes that there are two individuals involved in the game, and each individual in the game has two strategy choices: cooperation and betrayal [20]. When co-operation is chosen, both individuals get higher payoffs. When jointly choosing betrayal, both individuals get lower gains. When one individual betrays unilaterally and the other chooses

to cooperate, the betrayer gets the highest gain and the cooperator gets the lowest gain. According to this setup, the betrayal strategy is the optimal choice for each individual. The payoff matrix of the Prisoner's Dilemma game can be expressed as:

$$\begin{cases} T > R > P > S \\ 2R > P + S \end{cases} \tag{5}$$

C and D in the payoff matrix denote the individual's choice of a cooperative strategy versus a betrayal strategy. R, S, T, and P are the payoff parameters whose relationships satisfy $T > R > P > S$ and $2R > P + S$. The Prisoner's Dilemma game is often employed because it reveals the conflict between individual and collective rationality, and is therefore often used to investigate which mechanisms enable cooperation. While the Prisoner's Dilemma game is a symmetric game with two players, the public goods game is a game in which multiple players participate. In a public goods game, multiple people form a group to play the game. The amount of money invested in the group by the cooperators is c and no money is invested by the betrayers. The total amount of money received by the group can be appreciated by a factor of r. After the appreciation, the total gain is divided equally among all individuals in the group, regardless of whether they adopt cooperative strategies or not.

II. B. 2) Complex network game models

A complex network game is composed of a triad $\Gamma_g = (G, \{S_i | v_i \in V\}, \{U_i | v_i \in V\})$, where:

(1) $G = (V, E)$ is a network.

(2) Each element in node set $V = \{v_1, v_2, \cdots v_n\}$ represents a game participating individual, strategy set S_i is the set of strategies that individual $v_i \in V$ can choose, and each element in set $S = \{s_1, s_2, \cdots s_n\}$ represents the strategy chosen by each Bo and individual.

(3) $U_i : \prod_{v_j \in V} S_j \times S_i \to$ □ is the payoff function of individual $v_i \in V$, and N_i is the neighbor of node v_i.

In a general network game, the game individuals represented by network nodes form a network structure, and the network structure relations represent all the neighbors of an individual. The payoff function of each individual is only related to the individual strategies with which it interacts in the game. Compared to general game models, network games are characterized by giving specific structural information about the interactions between individuals, whereas classical game models assume that the relationships between individuals in the game are completely mixed.

Since this network structure is the same for each time step and the relationships between the game individuals do not vary with the network, the time labeling is omitted. In the following definition, we make the same treatment in order to simplify the notation.

When the game played by each pair of neighboring nodes in the network is a two-player symmetric game, such a game is said to be a pairwise interaction network game. Specifically, given a two-player symmetric game:

$$\Gamma_2 = \left(\{v_i, v_j\}, \{s_i, s_j\}, \{u_i, u_j\} \right) \tag{6}$$

$S_i = S_j = S_0$ by its symmetry requirement and holds for any $s = (s_i, s_j) \in S_0^2$, $u_i(s) = u_0(s_i, s_j)$, $u_j(s) = u_0(s_j, s_i)$. Thus, a two-player symmetric game can be denoted as $\Gamma_2 = (S_0, u_0)$.

A pairwise interactive network game generated by a two-player symmetric game can be defined as, given a network game $\Gamma_g = \left(G, \{S_i | v_i \in V\}, \{U_i | v_i \in V\} \right)$ and a two-player symmetric game $\Gamma_2 = (S_0, u_0)$. If:

(1) For all individuals $v_i \in V$, the set of strategies satisfies $S_i = S_0$.

(2) For all individuals $v_i \in V$, its payoff function is satisfied:

$$U_i(s) = \sum_{v_j \in N_i} u_0(s_i, s_j) \tag{7}$$

where $N_i = \{v_k \in V | a_{ik} = 1\}$ is a neighbor of node v_i.

Network game Γ_g is a pairwise interaction network game generated by a two-player symmetric game Γ_2, and $\Gamma_2(S_0,u_0)$ is called a local meta-game of pairwise interaction network game Γ_g. The pairwise interaction network game can be simply denoted as $\Gamma_g=(G,\Gamma_2)$.

A pairwise interaction network game based on information propagation with belief matching is defined, given a network game $\Gamma_g=\left(G,\{S_i|v_i\in V\},\{U_i|v_i\in V\}\right)$ and a two-player symmetric game $\Gamma_2=(S_0,u_0)$. If:

(1) The set of strategies satisfies $S_i=S_0=\{A,B\}$ for all individuals $v_i\in V$.

(2) The amount of information (the proportion of strategies A chosen in the history) of the game individual v_j at a given time is:

$$x_j=\frac{\sum_1^t s_j(t)}{t} \tag{8}$$

(3) For any pair of neighboring nodes $(v_i,v_j)\in E$, the belief of individual v_i's strategy choice for v_j is:

$$b_{ij}=x_j\left(\frac{\sin\alpha U_i}{e^{\beta U_i}}+1\right)(v_i,v_j)\in E \tag{9}$$

(4) The payoff function is satisfied for all individuals $v_i\in V$:

$$U_i(s)=\sum_{v_j\in N_i^m}u_0(s_i,s_j) \tag{10}$$

Where, N_i^m is the node in the neighborhood of node v_i that matches its belief. α, β are the regulation parameters of the belief generation function. $\sum s_j$ is a summation over time indicating the total number of times in history that individual v_j has chosen strategy A.

II. C.Economic radiation theory

Industrial economic radiation refers to the flow and transfer of capital, talent, technology, markets and other factors, as well as the spread of ideas, ways of thinking, habits and other aspects of life between regions with relatively high levels of economic development and modernization and those with more backward economic development [21]. The modern ideology and way of thinking are used to replace the old habitual forces that are contrary to modernization, so as to further improve the efficiency of economic resource allocation.

Theories of economic radiation include the growth pole theory, the point-axis development theory, the economic gradient theory, the cyclic cumulative causation theory, the center-periphery theory, the inverted "U" shape economic development theory, and the knowledge spillover theory. In this study, we seek to apply the theory of economic radiation to describe and explain the energy relationship between different growth poles and polarized regions in the development of sports economic growth poles, i.e., how all kinds of economic elements, capital, science and technology, human resources and institutions are radiated or flowed between different radiation circles.

II. D.Regional economic theory

II. D. 1) Regional economies

A regional economy is a production complex resulting from the interaction of internal factors and external conditions of economic development in a given region. A regional development entity that has a certain territorial scope and is closely integrated with economic factors and their distribution. The regional economy, reflecting the objective laws of economic development within different regions, and the interrelationship of connotations and extensions.

II. D. 2) Sports economy

Sports economy, sports economy refers to the organic integration of mass sports life and economic behavior related to it as a special industry from the point of view of production and operation. The relative sports industry refers to the industry that provides all kinds of sports services to the whole society in the form of activities, and it is the general name of sports service industry.

There are mainly the following expressions about the concept or connotation definition of sports industry:

(1) Sports industry is sports service industry

The sports industry is thus divided into fitness and entertainment industry, competition and performance industry, consulting and training industry, sports brokerage industry, sports tourism industry, sports betting industry and so on.

(2) Sports industry is all the production and operation activities related to sports

The essence of sports industry is the economic value contained in sports. The production and management activities carried out by market economy means to explore the economic value of contemporary sports constitute the sports industry existing in the real economic life. Therefore, sports industry is an industry that provides all kinds of sports material products and services to the whole society and meets the diversified sports consumption demands of the masses, which is composed of the production and operation of sports material products and sports service products, including not only fitness and entertainment, competition and performance, consulting and training, sports brokerage and other service industries, but also the production and operation of sports clothing, sports equipment, sports food and sports drinks. Therefore, this viewpoint is called the broad sports industry economy.

III. Study on the relationship between the sports economy and regional economic growth

III. A. Sports Economic Growth Pole Model

This section will be based on the statistical data and estimation data of the development of the sports industry, combined with the results of the three major theories, namely, the theory of full life cycle cost, the theory of evolutionary game and the theory of economic radiation. The model A_{ij} of sports industry agglomeration effect, the model D_i of dominant industry and the model C_{ij} of "city attraction" and their related indexes and weights will be set up, and then the Douglas function will be used for the comprehensive operation. Finally, the regional sports industry growth pole model $G_{s(ij)}$ is obtained as follows:

$$G_{s(ij)} = A_{ij}^{\alpha} D_i^{\beta} C_{ij}^{\gamma} \tag{11}$$

To wit:

$$\begin{aligned} G_{s(ij)} &= \left(a_1 CR(m)_{ij} + a_2 G_{ij} + a_3 LQ_{ij}\right)^{\partial} \left(B_i X_i\right)^{\beta} \left(\frac{EM_i \times EM_j}{\sum_{f=1}^{n} \beta_{ij} T_{ij} C_{ij}}\right)^{\gamma} \\ &= \left(a_1 \frac{\sum_{i=1}^{m} X_i}{\sum_{i=1}^{n} X_i} + a_2 \sum_{i}^{n=1} \frac{M_i / Q_{i+1}}{M_{i+1} / Q_i} + a_3 \frac{E_i / E}{N_i / N}\right)^{\partial} \left(B_i X_i\right)^{\beta} \left(\frac{EM_i \times EM_j}{\sum_{f=1}^{n} \beta_{ij} T_{ij} C_{ij}}\right)^{\gamma} \end{aligned} \tag{12}$$

Among them, $CR(m)_{ij}$ indicates the market concentration of the sports industry, that is, the output value of the top i enterprises accounts for the proportion of the total industrial output value, and the larger the value is, the higher the concentration of the industry is. G_{ij} indicates the Gini coefficient of location, reflecting the degree of spatial agglomeration, M_i / Q_{i+1} indicates the proportion of employment in i region j sports industry to the proportion of employment in national j industry, and M_{i+1} / Q_i indicates the proportion of employment in i region to the proportion of employment in national industry.

LQ_{ij} denotes the locational area:

$$LQ_{ij} = S/P = \frac{E_i / E}{N_i / N} \tag{13}$$

In the formula, S and P are the proportion of the region's GDP to the national GDP and the proportion of the region's population to the national GDP, respectively, which are used to measure the spatial distribution of factors in a certain region or to reflect the degree of specialization of a certain industrial sector. Where $D_i = B_i X_i$ denotes the dominant industry index.

From the above formula, bringing in relevant data, the regional sports economic growth pole model can be constructed.

III. B. Structure of the regional sports economy

III. B. 1) Specialization of the structure of the sports economy

From the viewpoint of spatial scale, the sports industry structure system is composed of a number of regional industry structure systems, if each regional subsystem can establish an industry system based on its own advantages with advantageous production factors as specialized sectors, and the products of specialized sectors are exported and exchanged to the outside world in large quantities. Then a reasonable economic division of labor can be realized between the regional subsystems, thus affecting the regional subsystems and even the structure of the sports industry. Therefore, the specialization of regional sports industry structure becomes a yardstick for converting various regional resources into the advantages of regional industry specialization, the reasonable distribution of the region, and even the relative development level of the industry placed in the national scope. The indexes for measuring industrial structure specialization mainly include location entropy and specialization index.

Location entropy reflects whether the regional industrial development has the specialization advantage. Its formula is:

$$L_{ij} = \left(Q_{ij}/Q_i\right)\Big/\left(Q_j/Q\right) \tag{14}$$

In the formula, L_{ij} is the moisture content of location, whose value is greater than 1 means that sports in the region has the advantage of specialization, and vice versa. Q_{ij} is the total output value of the j th sector of the sports industry in the i rd region, Q and Q_j are the total output value of all sports industries in the whole country, and the output value of the j th industry of the sports industry in the whole country, respectively.

Specialization index measures the degree of specialization and concentration of regional industrial structure to reveal the basic pattern of regional division of labor, and the formula is:

$$S_i = \sum_i^n \left[\frac{a_{ij}}{a_j} - \frac{a_i}{a}\right] \tag{15}$$

where, s_i is the regional sports industry specialization index, its value is greater than 1, and the larger the value indicates the higher degree of specialization and concentration of the industry in the region. a_{ij} and a_i represent the output value and total output value of the j sector of the sports industry in the i region respectively. a_j denotes the total output value of the i th sector of the national sports industry, and a denotes the total output value of the national sports industry.

III. B. 2) Diversification of the structure of the sports economy

The establishment of regional division of labor and cooperative relations is based on the principle of comparative advantage, and the basic requirement of the principle of comparative advantage is the formation of mutually different and interconnected production systems and diversified regional sports industry structures in accordance with the conditions of the different levels of resources, technology, and labor productivity in each region, that is:

$$\gamma = 1 \div \sum_i^n xi^2 \tag{16}$$

where γ is the diversification index of the structure of the sports industry, xi is the proportion of each industry in the total output value of the sports industry, and n is the number of industrial sectors.

III. B. 3) Adaptation of the structure of the sports economy

The conversion speed and ability of regional sports industry structure is the inevitable requirement for sports industry to adapt to and support regional socio-economic development, and it is also the embodiment of the ability of coordinated and efficient development of regional sports industry structure and regional economic, social and environmental resources. As an important part of regional economic development, sports industry should have strong conversion ability to promote the rapid development of economy, so as to form the interactive formation of economic growth to support the structural adjustment of sports industry and optimization of sports industry structure to feed the economy. Therefore, the conversion speed of sports industry structure is used to reflect the

comprehensive coordination ability of regional sports industry structure and regional economic resources and elements, i.e.:

$$\delta = \sqrt{\sum_{i}^{n} \frac{(A1 - A0)^2 \, ki}{A0}} \tag{17}$$

where, i represents the regional sports industry each industry $(n = 1,2,3)$. Ai is the average annual growth rate of the sports industry sector, $A0$ is the growth rate of the regional economic growth in the study time period, ki is the proportion of the regional sports industry sector i industry to the regional economy.

The conversion direction reflects the comprehensive quality and potential of the industrial structure of a regional sports industry. The rationalization of the layout of the regional sports industry structure is the flow of all kinds of regional resources among industries in accordance with the principle of comparative interests, so that the utilization efficiency of production factors can be constantly improved, thus realizing the enhancement of the overall efficiency of the inter-regional industrial structure. Therefore, the direction of structural transformation of sports industry is used to reflect the process of sports industry structure on the optimal allocation and effective utilization in order to promote the coordinated and efficient development of regional economy. Constructing the coefficient θ of the direction of structural transformation of the sports industry, i.e:

$$\theta = \frac{1 + Ai}{1 + A0} \tag{18}$$

In the formula, i represents each industry of the regional sports industry $(n = 1,2,3)$. Ai is the average annual growth rate of the i industry, $A0$ is the average annual growth rate of the regional economy in the study period, and θ is the coefficient of structural change of the i regional sports industry.

IV. Mechanisms of sports economic development for regional economic growth

IV. A. Numerical simulation of the system

In order to visualize the operation status of the system of sports economic development and regional economic growth, this paper will carry out a series of game simulation operations for this system. The important parameters of the system are assigned as follows:

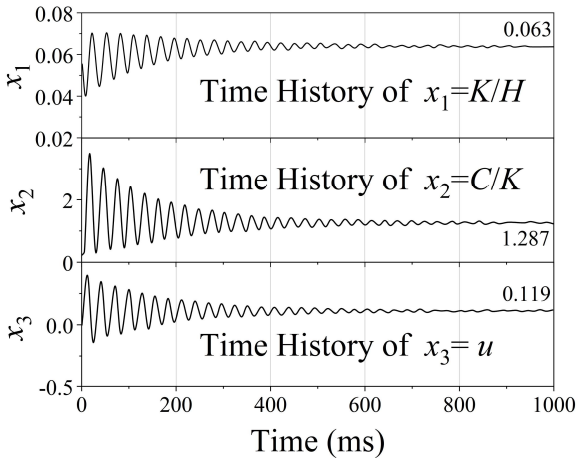
$$B = \frac{1}{20},\ \rho = 0.0500,\ n = 0,\ \delta = 0 \tag{19}$$

where B is the growth rate of the sports economy, ρ is the time preference rate, n is the growth rate of the sports consuming population, and δ is the depreciation rate of physical capital.

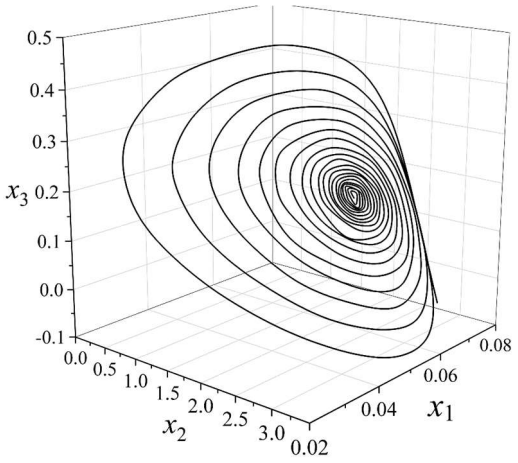
IV. A. 1) System runtime numerical simulation

Fixing the market adjustment coefficient of $\alpha = 0.1$, it can be calculated that the elasticity coefficient of consumer utility of sports tourism reaches the critical point at $\sigma \approx \sigma_0 = 0.05$. It is easy to find that when $\sigma \in [0, \sigma_0]$, the system operation of sports industry development and regional economic growth will converge to its equilibrium point near $E(x_1^*, x_2^*, x_3^*)$ after a period of adjustment operation. The change of consumer utility elasticity coefficient of sports industry σ in this range can only change the adjustment time of the system and the speed of convergence to the equilibrium point. However, when $\sigma \in [0, \sigma_0]$, the system will have Hopf bifurcation near its equilibrium point, and the system operation will be changed from stable state to unstable state.

Taking $\alpha = 0.1$, the value of σ in the critical state is calculated to be 0.155. In this paper, we observe that the operation of the system in state $\sigma = 0.01$ is shown in Fig. 2. It can be seen that when $\sigma = 0.01$, it is clear that the value of σ is much lower than the critical state $\sigma_0 = 0.155$. As mentioned earlier, when $\sigma \in [0, \sigma_0]$, the operation of the system will always be adjusted after a period of time to converge to its equilibrium point $E(x_1^*{=}0.063, x_2^*{=}1.287, x_3^*{=}0.119)$ near. The three variables x_1, x_2 and x_3 of the system of sports economic development and regional economic growth converge rapidly to the vicinity of its equilibrium point, which is reflected in the time course graph that the curve converges to a straight line after oscillation, and in the phase diagram that the curve converges to the vicinity of a point after rotation, which is the stabilized growth path of the system of sports economic development and regional economic growth.



(a) Operation of the System



(b) Phase Diagram of the System

Figure 2: The time history of the system when σ=0.01

In this paper, it is found that at the point of stabilization, the time-course curve of the system no longer converges to the vicinity of its equilibrium point. In other words, at this point, the system no longer runs along the path of stable growth, but enters a cyclical state. We can interpret this cyclical state as a growth cycle in the economic growth system, which can be categorized into different phases, such as adjustment, growth, and recession. In this case, it is necessary to follow the corresponding external incentives, policy adjustments to make the development of the sports economy and the regional economic growth system harmonious symbiosis, synergistic development.

IV. A. 2) Numerical simulation of the system during stabilization

In reality, sports economic development and regional economic growth systems do not always follow the ideal path of stable growth. Due to local development strategies, policy inclination, market stimulation and other factors, the harmonious symbiosis between sports economic development and regional economic growth system will be broken. That is to say, once the sports economic development and regional economic growth system bifurcated, so as to enter the cyclical growth and decline process, how the government response is also one of the main issues to be studied in this paper. Next, this paper will simulate the stability of the limit (i.e., the regional economic growth cycle) of the system under the condition of the system bifurcation.

The first Lyapunov coefficients of the system are calculated by substituting the key parameters given at the beginning of this section into. And simulate it with α , σ as dynamic variables, the first Lyapunov coefficient surface can be obtained as shown in Fig. 3. It can be seen that the first Lyapunov coefficients are all greater than zero when they are near the zero point, while the other parts of the first Lyapunov coefficients are less than zero. When the Lyapunov coefficients are less than zero, it means that the limit ring generated by the bifurcation of the system is stable.

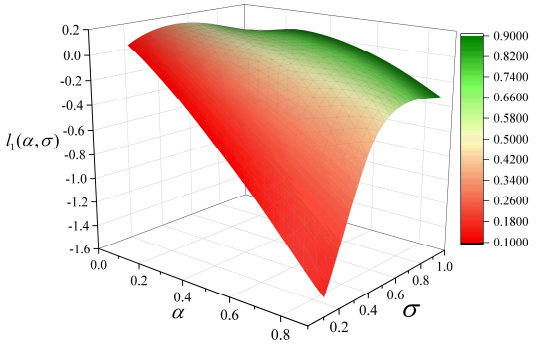


Figure 3: Surface of the first Lyapunov coefficient

Fix $\alpha = 0.8$ and observe the variation of the first Lyapunov coefficient with σ as shown in Fig. 4. It can be seen that when $\sigma \in (0.405,1)$, the first Lyapunov coefficient is positive. And when $\sigma < 0.405$, the first Lyapunov coefficient is negative. This means that the government in the process of market regulation, when the market regulation is too strong, sports economic development and regional economic growth system operation into a cyclical oscillation state, at this time should control the development scale of the sports industry. To ensure that the cyclical growth and decline at this time, within a relatively controllable range. In order to take further measures for the sports economy market transformation, try to promote the regional economic growth stability.

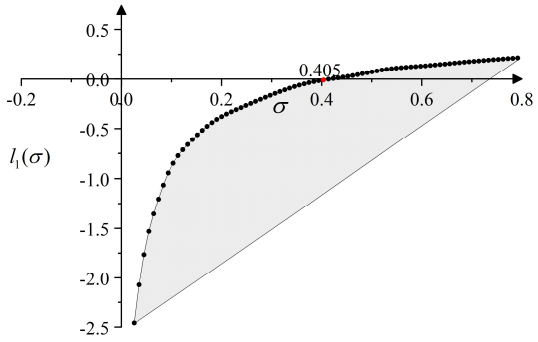


Figure 4: When α = 0.8, the first Lyapunov coefficient is associated with the change of σ

When the market regulation is small ($\alpha = 0.3$), but it happens that there is a cyclical oscillation in the growth of the sports market, a similar analysis is shown in Figure 5. It can be found that when the dynamic variable σ is 0.3, the sports economic development and regional economic growth system takes the maximum value of 0.1202. Therefore, when the dynamic variable $\sigma \geq 0.3$, at this time, the government should increase the speed of economic development of the sports industry, strengthen the publicity, and put forward a variety of concessionary policies, tax reduction policies to rapidly increase the sports market share, in order to ensure that the cyclical growth and recession at this time in a relatively controllable range. In order to ensure that the cyclical growth and recession are within a relatively controllable range, and to stabilize the market for further measures to be taken.

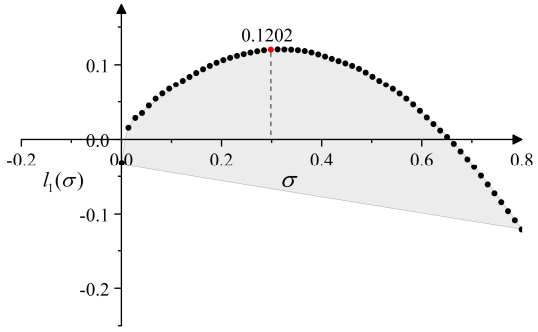


Figure 5: When α = 0.3, the first Lyapunov coefficient is accompanied by the change of σ

IV. B. Sports industry spatial evolution game simulation

IV. B. 1) Spatial aggregation of the regional sports economy

Firstly, we explain the phenomenon that the spatial agglomeration of regional sports industry is enhanced when the weight factor $\beta > 0$.

Assuming that no two individuals with the same degree are connected to each other in this region when $\beta > 0$, weight $\left(\frac{k_s}{k_l}\right)^{\beta} \to 0$. At this point, the phenomenon of “self-sufficiency” in the sports industry occurs, i.e., each region only invests in its own participating agglomeration circle, in which case each human capital participating in the agglomeration receives the same benefit, i.e., $P_C = r - 1$, while the discrete people who do not pay for the capital have no benefit, $P_D = 0$.

According to the replication dynamics, individuals will adopt the strategies of individuals with higher returns, i.e., the discrete individuals imitate the behavioral strategies of the agglomerators with a higher probability, resulting in a fast and stable system evolution. In this state, all sports industries in the region will uniformly maintain the strategy choice of agglomeration. Therefore, for larger weight factor β, the spatial agglomeration behavior of the sports industry economy can evolve and promote the prosperity of the regional sports industry, while the discrete players eventually disappear from the system completely.

In order to make a more in-depth observation of the phenomenon of weight factor β, which affects the spatial agglomeration of the sports industry, this paper derives the average return of the sports industry in the case of the evolutionary stability of the system as shown in Figure 6. It can be seen that individuals with different degrees of connectivity have almost equal average returns, especially so for individuals with medium degrees. The reason for this is that the sports industry has to gain from the agglomeration circle centered on itself, and this tendency is more pronounced as the value of β increases. Discrete individuals and can continue to parasitize the help of altruistic agglomerators, and therefore must mimic the agglomerator's strategy.

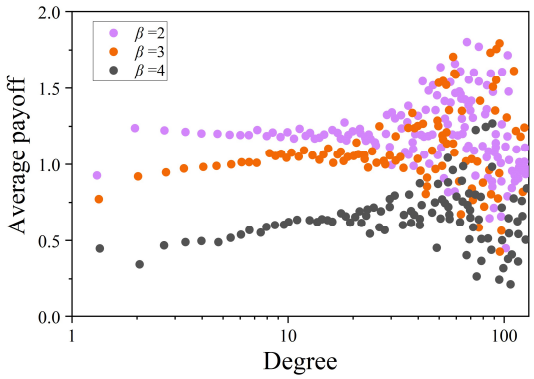


Figure 6: Average revenue of sports industry under stable condition

An increase of β also produces a positive feedback, i.e., the less the agglomerators help the discrete individuals, the more it favors the development of regional human capital agglomeration. Another result is that for a fixed multiplication factor of r, the average return of all individuals increases with the degree of agglomeration.

Considering the government policy support, which will promote the spatial agglomeration development of the regional sports industry, this paper makes some extensions to the original model to study the case where individual returns are normalized by the number of connections, i.e:

$$W_{s_i \leftarrow s_j} = \frac{1}{1+e^{\left(\frac{F_i}{F_j}\right)^k}} \tag{20}$$

where, F_i and F_j denote the strategy adaptability of the sports industry i and j respectively, and k represents the strength of choice in strategy shifts. $k \to 0$ implies that the individual, always adopts the individual strategy with higher adaptability and the probability that this happens is 1. $k \to \infty$ implies that the individual's strategy choice is non-ideal and which strategy is adopted is random. The numerical simulation results are shown in Fig. 7, and it is obvious that there is also an agglomerator trough in the case of normalized returns in the β-value [-1, 1] interval in the middle zone, which indicates to some extent the prevalence of agglomerator crises in regional human capital.

In general, through the spatial development of sports industry spatial development dynamics of spatial agglomeration development of evolutionary game system simulation. This paper argues that the government support policy, can well promote the phenomenon of spatial agglomeration of the sports industry. But there is also a medium-sized weight factor parameter region does not support the agglomeration environment, sports economy spatial development dynamics mechanism in the individual different decision-making process, has a more general robustness.

IV. B. 2) Analysis of the mechanisms driving regional economic growth

There are extensive links between regional economies, and the spatial factors of regional economies are characterized by both spatial autocorrelation and spatial heterogeneity. With the development of new economic

geography, it has been found that economic problems are not only affected by geographic space, but also by economic space, industrial space and social relations space. The so-called industrial spillover refers to the positive influence of regions with advanced industrial development on regions with low industrial development. From the growth pole theory and numerical simulation results, it can be seen that:

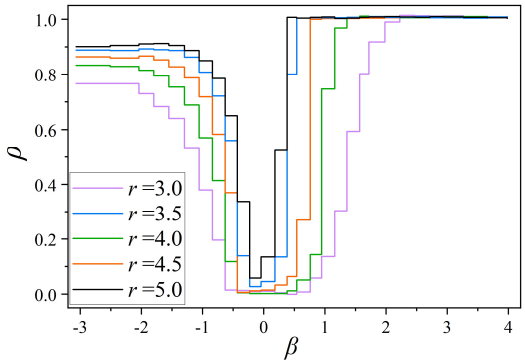


Figure 7: The trend of cooperation level with β value

(1) The development of sports industry will start from the region (one or several growth poles) with aggregation advantages in economy, resources, transportation and culture, and then diffuse and spread to the surrounding regions.

(2) The sports industries in different regions will influence each other (promote or inhibit), especially the spillover effect is more obvious in neighboring regions.

From the phenomenon of spatial agglomeration of the sports industry, it can be seen that:

(1) there is an external economic effect, there are a large number of sports enterprises in the cluster area, and the scale and influence of individual enterprises may be small, but the enterprises in the cluster area practice a high degree of division of labor and collaboration with each other, and the sports manufacturing industry and the sports service industry have specialized production, and the production efficiency is very high, and the products produced are constantly entered into the market outside the region, so as to make the whole industrial cluster obtain a kind of external scale Economy.

(2) There are learning and innovation effects, sports industry cluster is conducive to cultivating the learning ability and innovation ability of sports enterprises, and the geographic and economic proximity of enterprises leads to considerable competitive pressure on enterprises, forcing them to continuously carry out technological innovation and organizational management innovation.

(3) Competition among enterprises in regions with a high degree of development of the sports industry has led to a large number of small enterprises withdrawing from the local market and moving to regions with a low degree of development of the industry in order to obtain growth opportunities. In addition, large enterprises that have won the market in the competition tend to move into other regions through investment and other means in order to gain more profits due to the expansion of their business scale.

V. Conclusion

(1) Main work and results

In this paper, the stability analysis, the existence of economic growth cycle and stability analysis of the spatial development power mechanism of the sports economy was carried out by using the complex network game model. The following conclusion is drawn, namely, the development of sports industry under a certain scale plays a role in promoting the overall economic growth of the region, and this equilibrium point is $E(x_1^*=0.063, x_2^*=1.287, x_3^*=0.119)$. On the contrary, sports industry exceeding a certain scale may have a negative impact on the development of the overall economy, so it should not be blindly expanded and over-developed. When the development scale of sports industry is small, the government should actively intervene in the market, increase the publicity and support for the sports tourism industry, and implement a series of tax reduction and profit-making policies to promote the rapid and healthy development of the sports tourism industry and drive the growth of the overall tourism economy. When the development scale of sports industry is large, but there is no market oscillation, the government should implement the policy of decentralization, reduce the intervention in the market, give full play to the leverage of the market itself, so that the sports market can regulate itself, which will make the regional economic growth system return to a stable growth path quickly.

(2) Policy Recommendations

In view of the characteristics of policy effect lag, combined with the actual development of demonstration bases, it is recommended that local governments should strengthen the policy guidance for demonstration bases, incorporate the base development into the regional sports industry development plan, reasonably formulate the development plan of bases, actively set up the leading group of sports industry in the demonstration bases or the organization and management institutions, and steadily promote the formulation and implementation of the implementation rules for the management of the base's sports industry. At the same time, through the formulation of preferential policies such as land policy, tax policy, financial special (including subsidy) fund policy, etc., it has stimulated the enthusiasm of the market main bodies in the demonstration bases, and solidified the foundation for the high-quality development of the demonstration bases.

It is suggested that the regional cities jointly approved as demonstration bases should change from regional competition to regional collaborative innovation, encourage regional resource sharing, build a digital regional sports industry platform, implement various innovation policies, improve regional collaborative innovation ability, promote regional industrial upgrading, drive the overall improvement of the regional economic development level, and radiate and lead the development of sports industry in the neighboring cities.

References

[1] Kobierecki, M. M. , & Pierzgalski, M. . (2022). Sports mega-events and economic growth: a synthetic control approach:. Journal of Sports Economics, 23(5), 567-597.

[2] Norcliffe, G. , & Decosse, S. . (2022). Global player production networks: gaining value in the national hockey league. Geoforum.

[3] Song, S. . (2022). The effect of sports performance entrepreneurial project by entrepreneurial spirit. Frontiers in Psychology, 13.

[4] Wetzel, H. A. , Hattula, S. , Hammerschmidt, M. , & Heerde, H. J. V. . (2018). Building and leveraging sports brands: evidence from 50 years of german professional soccer. Journal of the Academy of Marketing Science, 46(4), 1-21.

[5] Islam, M. Q. . (2019). Local development effect of sports facilities and sports teams: case studies using synthetic control method. Journal of Sports Economics, 20(2), 242-260.

[6] Jakar, Gidon S.Razin, EranRosentraub, Mark S.Rosen, Gillad. (2018). Sport facility development: municipal capital and shutting out the private sector. European Planning Studies, 26(6).

[7] Tsekouropoulos, G. , Gkouna, O. , Theocharis, D. , & Gounas, A. . (2022). Innovative sustainable tourism development and entrepreneurship through sports events. Sustainability, 14.

[8] Forsdike, K. , Marjoribanks, T. , & Sawyer, A. M. . (2017). 'hockey becomes like a family in itself': re-examining social capital through women's experiences of a sport club undergoing quasi-professionalisation. International Review for the Sociology of Sport, 101269021773129.

[9] Shu, Y. U. , Qiu, C. , & Yang, R. . (2022). Spatial characteristics of sports tourism destination system based on data fusion and data mining. Mobile information systems, 2022(Pt.11), 1897852.1-1897852.12.

[10] Guangning, T. . (2012). Swot analysis on china's sports industry and its developing strategy. Journal of Shenyang Sport University, 84(3), 401–410.

[11] Agha, N. , & Rascher, D. . (2021). Economic development effects of major and minor league teams and stadiums. Journal of Sports Economics, 22.

[12] Zhang, J. , Gan, J. R. , Wu, Y. , Liu, J. B. , Zhang, S. , & Shao, B. . (2021). Research on the resilience evaluation and spatial correlation of china's sports regional development under the new concept. Frontiers in psychology, 12, 763501.

[13] Li, L. . (2019). Configuration of public sports venues in china's counties under the background of urbanization. Open House International.

[14] Zou, X. , Kayani, S. , Wang, J. , Imran, M. , María Luisa Zagalaz Sánchez, & Lara Sánchez Amador Jesús, et al. (2019). A study on the relationship between urban residents' perception of recreational sports and their participation in recreational sports: based on gender differences. Sustainability, 11.

[15] Li, J. , Huang, S. , Min, S. , & Bu, T. . (2022). Modeling the driving factors of the value added in the chinese sports industry: a ridge regression. Sustainability, 14.

[16] Dong, B. . (2022). Dynamic modeling of high-quality development of sports industry driven by big data digital economy. Mobile information systems, 2022(Pt.6), 9131081.1-9131081.9.

[17] Chen, J. , Cai, C. M. , & Zhang, T. T. . (2023). Analysis of the spatial and temporal evolution process and development trend of innovation capability of chinese sports industry. plos one, 18(8).

[18] Luo, M. , & Chen, L. . (2024). The impact of regional sports industry aggregation on residents' health level in china. Scientific Reports, 14(1).

[19] Xu, J. , & Yang, R. . (2019). Sports industry agglomeration and green economic growth—empirical research based on panel data of 30 provinces and cities in china. Sustainability, 11(19), 5399.

[20] Chao Luo,Xiaolin Zhang & YuanJie Zheng. (2017). Chaotic evolution of prisoner's dilemma game with volunteering on interdependent networks. Communications in Nonlinear Science and Numerical Simulation407-415.

[21] Qiu Weilin. (2020). Analysis of Radiation Effect of Coastal Economic Circle Based on Space Vector Model. Journal of Coastal Research(sp1),322-325.