Evolution of Multi-Entity Collaborative Innovation of Sports Industry Cluster Based on Complex Network

Shanshan Zhao[1*]

Abstract

Under the influence of the dual-wheel driven mechanism of the economy, diverse market demand imposes greater demands on enterprises in the sports industry cluster, and the diffusion of production technology innovation in the sports industry cluster is developing and evolving towards multi-entity collaboration. However, few existing studies on the behavior and strategy of multi-entity collaborative innovation examine clusters in the sports industry. This study seeks to analyze the evolution of multi-entity collaborative innovation within a complex network-based sports industry cluster. Utilizing research methods such as questionnaire design, data collection, variable measurement, and structural equation modeling, this study employed SPSS and AMOS to perform data analysis and model analysis, and empirically validated the theoretical model and research assumptions. Last but not least, the corresponding experimental results were presented, which demonstrated the efficacy of the proposed analysis method and the fact that innovation investment intensity has a positive influence on maximum enterprise benefit and cluster sales.

Keywords: complex network; sports industry cluster; multi-entity; collaborative innovation; evolution

1. Introduction

(Bhatia, 2020; Ditizio, 2018; Kim & Kim, 2023; Sawan et al., 2020) The sports industry is the aggregation of entities engaging in similar economic activities in order to provide sports products to the general public and similar economic sectors. Both tangible sporting objects and intangible sports services comprise sports products. The economic sectors of the sports industry include not only market-based businesses, but also institutions, social organizations, and even individuals engaged in business activities. The industrialization of China's sports market began in the 1980s, and by the mid-1990s, a relatively complete system had been established. During this time, sports advertising, sports construction, sports gambling, sports tourism, sports goods, and other specialized industries were fully developed (Deng, 2022; Li et al., 2020; Li, 2013; Li & Tong, 2017; Lin et al., 2016; Meng, Sun, & Wu, 2015; Tang et al., 2022)

In terms of regional practice, under the influence of the dual-wheel driven mechanism of the economy, cross-region industrial collaborative innovation has become the norm, and enterprises in the sports industry cluster must meet more stringent market demands (Li & Xing, 2020; Mingxing et al., 2020; Wang & Ku, 2021; Yu & Chen, 2021). Trend-wise, the diffusion of production technology innovation in the sports industry cluster extends beyond single entities and is evolving toward multi-entity collaboration (Hansen, Mork, & Welo, 2019; He & Chen, 2020; Santoro, Bresciani, & Papa, 2020; Xuangong & Ning, 2020).

Jie, Xian, and Qi (2020) categorized major entities in civilian-military industrial collaborative innovation, analyzed their functions and roles, developed a theoretical framework for civilian-military industrial collaborative innovation, and proposed a number of recommendations for enhancing the effectiveness of industrial collaborative innovation (Zhu et al., 2022).

Cao, Yan, and Tang (2022) enhanced the Particle Swarm Optimization (PSO) algorithm in order to optimize the open collaborative innovation path of the energy industry in city clusters. First, authors integrated industrial agglomeration and city clusters into a unified analysis framework, adopted location entropy and spatial Gini coefficient to measure the degree of industrial clustering, and constructed an index system for evaluating the competitiveness of industrial clustering; second, a clustering index system was developed, and dynamic econometric method and spatial auto-correlation statistical method were applied to the analysis of clustering. Scholar Liu (2021) developed a collaborative innovation model for the manufacturing service and manufacturing industries on the basis of a two-dimensional asymmetric evolution game model. The model's stable evolution strategy was determined by solving the replicator dynamic differential equation on both sides of the game.

Based on a synthesis of previous research on collaboration theory, innovation networks, and collaborative innovation, this study defined the concept of multi-entity collaborative innovation and extracted the essential data from several

[1] School of Management, Zhejiang University of Technology, Hangzhou 310014, China
[*]Corresponding author's email: susanz0809@zjut.edu.cn

cases. After reviewing existing literature, it has been determined that world researchers in related fields generally focus on angles such as development mode or coordination mechanism of industrial clusters, few of them have considered the behavior and strategy of multi-entity collaborative innovation with sports industry cluster as the research target, and even fewer have analyzed the evolution of multi-entity collaborative innovation of sports industry cluster on the basis of theory. In light of these gaps, this study drew on the research accomplishments of its predecessors and conducted on-site surveys to examine the process of multi-entity collaborative innovation in the sports industry cluster from multiple perspectives.

This study examined the formation of complex collaborative innovation networks between enterprises and other innovation entities in the cluster during their force-joining and cooperation process, analyzed the impact of different collaborative innovation networks on the performance of cluster innovation, and proposed a comprehensive theoretical model to provide a novel approach to the study of cluster innovation mode and performance. In the second segment, this study sorted out the process of multi-entity collaborative innovation of sports industry cluster, presented the model's fundamental hypotheses, and analyzed the conditions under which such a cluster can engage in collaborative innovation. In the third segment, this study delved deeper into the evolution mechanism of collaborative innovation in the sports industry cluster and mapped out the evolution path in detail. This study utilized SPSS and AMOS to perform data analysis and model analysis, and empirically validated the theoretical model and research hypotheses. Finally, the corresponding experimental results were presented, demonstrating the efficacy of the proposed analysis method. Based on the theory of collaboration, this study analyzed the collaborative innovation behavior of multiple parties in sports industry clusters, thereby expanding the analytical framework of the formation of the cluster innovation advantage.

2. Literature Review

The study by Alonso Dos Santos, Calabuig Moreno, and González-Serrano (2022) found that innovation in sports products can attract the market to the advanced level because the public buys the new products. When consumers have the opportunity to purchase a variety of products, the marketing strategy for sports goods can be successful. In addition, Glebova and Desbordes (2021) found that new innovation and product performance is the most effective method to advance a sports product on the market with cluster-based market targeting. The novel product innovation in sports can attract niche market customers as well.

In addition, Raghavendra and Lingam (2020) emphasized that the retailing of sports products is the way forward to enhance the innovation and performance of the products. Similarly, when there is a new innovation in the sports brands, the dependability of the product's performance may become conceivable. Lianju et al. (2023) concluded that the function of sports culture in the progression of sports product developments in any market is essential. When strategic actions are required to make sports culture more advanced and productive, sports products are beneficial for all markets. The success of sports performance depends on the accessibility of sports products in all markets.

Cavdar Aksoy et al. (2020) noted that sporting events are useful for encouraging consumers to purchase additional products. The innovation of the products is also considered a successful market-attraction strategy. The new wearable for sports can attract more individuals if they are designed to enhance sports performance. Wu (2021) concluded that people are attracted to sports products, but that these products should be equally accessible to everyone. The dependability of technological advancement can provide access to sports performance and guarantee the performance's market viability. Access to beneficial sports products can attract the public for the public's greater good. Sarazin and Couput (2021) demonstrated that sports performance and culture are essential for the development of sports-related products. When new products of sprots become available on the market, the athletes are ecstatic. The sports industry is negatively affected by the non-availability of sports products that meet market requirements. In the meantime, Song and Cheng's (2020) study concluded that the availability of sports information to respondents may represent the greatest opportunity for employment. When new technology is applied to the creation of sports goods, success in athletic performance is attainable. In this manner, public access to these products can enhance sports performance.

Jiang et al. (2022) emphasized that successful sports brands can be created when fruitful working opportunities are created. Access to sports products by the public is one method to influence the public's attitude toward sports. Taghinejad, Dehghanpouri, and Rajabi (2022) noted that the development of sports performance and sports culture is a successful strategy for attracting consumers in a more effective manner. In the absence of sports product awareness, it would be challenging for individuals to obtain superior sports services. More consumers can be attracted

to the purchase of sports products if the sport's culture and performance are reputable.

2.1 Basic hypotheses of the model

A sports industry cluster is an aggregation of multiple entities, including sports-related businesses, universities and colleges, research institutions, and even some financial institutions. There are behaviors of collaborative innovation among these entities. Before modeling, this research clarified the model's fundamental hypotheses in order to arrive at defensible conclusions; Figure 1 is a diagram of multi-entity collaborative innovation of sports industry cluster.

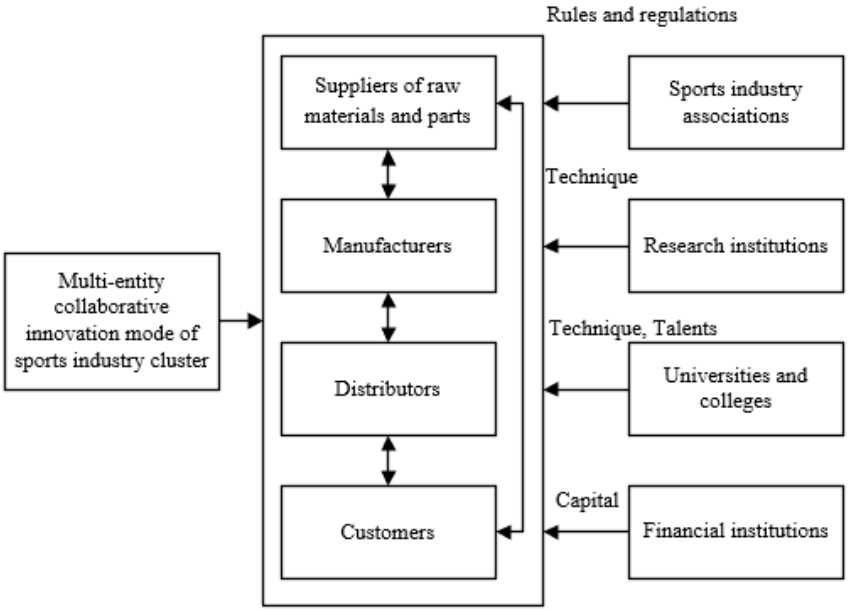

Figure 1. Multi-entity collaborative innovation of sports industry cluster

Hypothesis 1: There are many collaborative innovation entities in the cluster. For the convenience of research, it is assumed that only two parties, A and B. The collaborative innovation between A and B requires investment, which is measured in currency. Assuming: x ($0<x<1$) represents the share of innovation investment of X, y($y=1-x$) represents the share of innovation investment of Y, R represents the total innovation investment.

Hypothesis 2: Each collaborative innovation entity can choose between two strategies. Assuming: S represents the benefit of innovation, ω ($\omega>1$) represents the coefficient of the effect of collaborative innovation. If all entities adopt the collaborative innovation strategy, then S and ω are positively correlated. If entities do not adopt the collaborative innovation strategy, then there is $S=0$. Suppose only one entity adopts the collaborative innovation strategy. In that case, it is considered that the innovation investment of this entity is obtained by the other party, and the collaborative innovation behavior will not happen again thereafter.

Hypothesis 3: assuming t($0<t<1$) represents the probability of X adopting the collaborative innovation strategy, $1-t$ represents the probability of X not adopting the collaborative innovation strategy; w($0<w<1$) represents the probability of Y adopting the collaborative innovation strategy,$1-w$ represents the probability of Y not adopting the collaborative innovation strategy; wherein t and w can be regarded as the proportion of participating enterprises choosing the collaborative innovation strategy or the proportion of enterprises in the cluster supporting the collaborative innovation strategy.

Hypothesis 4: assuming there is a discount factor that can characterize the positive feedback incentive of collaborative innovation entities, which is represented by ρ ($0<\rho<1$), with the increase of the number of collaborative innovations, ρ is cumulative, and the greater the value of ρ, the better the effect of collaborative innovation, and the higher the benefit of collaborative innovation.

Hypothesis 5: When a collaborative innovation entity is choosing its collaborative innovation strategy, the collaborative innovation strategy of other entities is considered to be fixed already and won't affect the decision-making of the target entity. The influence of spillover effect of knowledge generated during the process of collaborative innovation on the innovation investment of entities is ignored.

Based on the above five hypotheses, an evolution analysis model was established to analyze the collaborative

innovation strategy of collaborative innovation entities (from now on referred to as "entity" for short) and the corresponding collaborative innovation function and innovation benefit matrix.

3. Methodology

Utilizing research methodologies such as questionnaire design, data collection, variable measurement, and structural equation modeling, this study utilized SPSS and AMOS to perform data analysis and model analysis. If all entities adopt the collaborative innovation strategy, then they will share the total innovation benefit in proportion to their innovation investment, so for party X:

$$S_{1X} = twx\omega(1+\rho)^{m-1}R - twxR = twxR[\omega(1+\rho)^{m-1} - 1] \quad (1)$$

For party *Y*, there is:

$$S_{1Y} = twyR[\omega(1+\rho)^{m-1} - 1] \quad (2)$$

If *X* adopts the collaborative innovation strategy while *Y* doesn't, then for *X* there is:

$$S_{2X} = 0 \quad (3)$$

For *Y*, there is:

$$S_{2Y} = t(1-w)xR \quad (4)$$

If *Y* adopts the collaborative innovation strategy while *X* doesn't, then for *X* there is:

$$S_{3X} = w(1-t)yR \quad (5)$$

For *Y*, there is:

$$S_{3Y} = 0 \quad (6)$$

If both parties do not adopt the collaborative innovation strategy, then there is:

$$S_{4X} = S_{4Y} = 0 \quad (7)$$

3.1 Conditions of collaborative innovation

Because the collaborative innovation behavior of entities is uncertain, what strategy *X* will choose depends on its expected return on collaborative innovation; that is, *X* will compare and judge S_X in the innovation benefit matrix, and $S_X>0$ is the condition for *X* to choose the strategy, there is:

$$\Delta S_X = \sum_{i=1}^{4} S_{iX}(T=1) - \sum_{i=1}^{4} S_{iX}(T=0) \quad (8)$$

Substituting into the above formula, there is:

$$\Delta S_X = wR[x\omega(1+\rho)^{m-1} - 1] \quad (9)$$

Because $S_X \geq 0$, there is:

$$x \geq \frac{1}{\omega(1+\rho)^{m-1}} \quad (10)$$

Similarly, in theory, the way for *Y* to choose the collaborative innovation strategy or not during the process of collaborative innovation is consistent with *X*, namely:

$$y \geq \frac{1}{\omega(1+\rho)^{m-1}} \quad (11)$$

Based on the above analysis, the conditions under which both entities *X* and *Y* choose the collaborative innovation strategy simultaneously can be described by the following formula:

$$\begin{cases} x \geq \frac{1}{\omega(1+\rho)^{m-1}} \\ y \geq \frac{1}{\omega(1+\rho)^{m-1}} \\ x + y = 1 \end{cases} \quad (12)$$

Through derivation, we can further analyze the conditions for enterprises in the sports industry cluster to choose to carry out collaborative innovation:

Condition 1: When the effect of collaborative innovation in the sports industry cluster is significant, even if the share of innovation investment is small, an enterprise will be willing to participate in collaborative innovation. On the contrary, the enterprise will be willing to participate in collaborative innovation only when its share of innovation investment is large.

For entities, when *m* and ρ are fixed, if ω is more significant, then *x* and *y* can be relatively small; but if ω is small, *x* and *y* must be relatively large.

Condition 2: The trust relationship between enterprises in the cluster will be formed gradually as the number of collaborative innovations increases; in this case, even if the share of innovation investment is small, an enterprise will be willing to participate in collaborative innovation. As for an enterprise that hasn't formed any trust relationship, it will be willing to participate in collaborative innovation only when its share of collaborative innovation is large.

For entities, when ω is fixed, if *m* and ρ are large, then *x* and *y* can be relatively small; if *m* and ρ are small, then *x* and *y* must be relatively large.

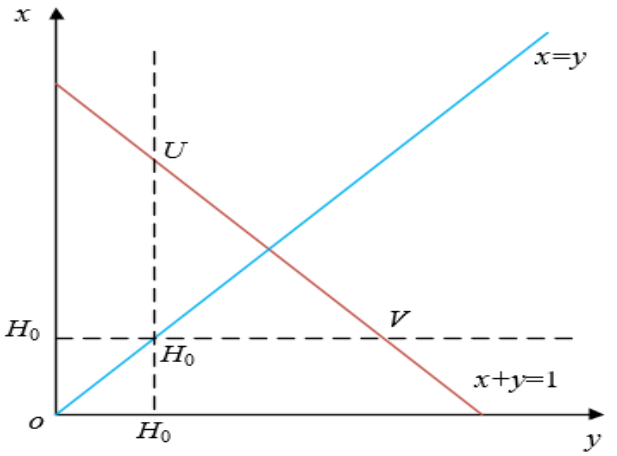

Figure 2. Interval of effective innovation investment of collaborative innovation entities

Condition 3: Figure 2 gives a diagram showing collaborative innovation entities' interval of effective innovation investment. The equivalence of innovation investment helps to increase the probability of enterprises in the cluster choosing the collaborative innovation strategy:

$$H_o = \frac{1}{\omega(1+\rho)^{m-1}} \quad (13)$$

Formula 12 can be converted into:

$$\begin{cases} x \geq H_0 \\ y \geq H_0 \\ x + y = 1 \end{cases} \quad (14)$$

Condition 4: The willingness of an entity to take the collaborative innovation strategy increases with the growth of the collaborative innovation probability of the other party.

Taking the partial derivation of w:

$$\frac{\partial \Delta S}{\partial w} = Rx\omega(1+\rho)^{m-1} > 0 \quad (15)$$

3.2 Evolution path of collaborative innovation network of enterprises in sports industry cluster

Since the introduction of the concept of innovation networks, the connotation of innovation networks has been widely acknowledged in related research disciplines around the globe. Scholars have now developed a unified understanding of the connotation and nature of innovation networks. Academics continue to pay close attention to innovation networks as an institutional arrangement to promote systemic innovation. The preceding section analyzed systematically the multi-entity collaborative innovation process of enterprises in the sports industry cluster and elucidated the collaborative effect of the game and cooperation between the entities. Then, with innovation advantage as a starting point, businesses in the cluster will establish a dynamically developing relationship network. Since there are both positive and negative feedback mechanisms in the game between entities during the process of multi-entity collaborative innovation, the constructed collaborative innovation network will exhibit a self-organizing characteristic. Next, the study will delve deeper into the evolution mechanism of the collaborative innovation network of enterprises in the sports industry cluster.

In existing studies, according to the different research content of enterprise collaborative innovation elements, the collaborative enterprise innovation can be divided into two types: internal element collaborative innovation and external element collaborative innovation. Entities in the first type of innovation are multiple management elements inside the enterprise, and entities in the second type of innovation are the enterprise and other organizations. Based on the evolution analysis model constructed in previous section, entities performing collaborative innovation have two equilibrium points $a^*=0$ and $a^*=1$ of their proportion in the cluster. $a^*=0$ corresponds to the situation that all enterprises do not choose collaborative innovation, and $a^*=1$ corresponds to the situation that all enterprises choose collaborative innovation. Besides, equilibrium point $b^*=u(y_1+d_1)/y_1(2u+r) = 1/2+r/u(1+d_1/y_1)$ indicates that the proportion of enterprises choosing to carry out collaborative innovation can be fixed and is affected by their shares of collaborative innovation. Assuming d_1 and y_1 represent the cost and benefit of the collaborative innovation of enterprises, u represents an enterprise's collaborative innovation benefit requirement, r represents the collaborative innovation investment of other entities. The ratio of u to r will affect the size of the equilibrium point.

a represents the proportion of enterprises choosing collaborative innovation, and it satisfies $0 \leq a \leq 1$, so the symbol of da/dp is only related to $[(2u+r)b-u]y_1-rd_1$. Considering the innovation investment ability and innovation requirement of related enterprises, the initial state is that the entities are willing to carry out collaborative innovation. When $b=1/2+r/u(1+d_1/y_1)$, $da/dp = 0$, the proportion of enterprises choosing collaborative innovation will remain unchanged. When $b>1/2+r/u(1+d_1/y_1)$, there is $da/dp > 0$, the proportion of enterprises choosing collaborative innovation will increase. When $b<1/2+r/u(1+d_1/y_1)$, there is $da/dp < 0$, the proportion of enterprises choosing collaborative innovation will decrease, ultimately, the collaborative innovation network of enterprises in the cluster will no longer exist.

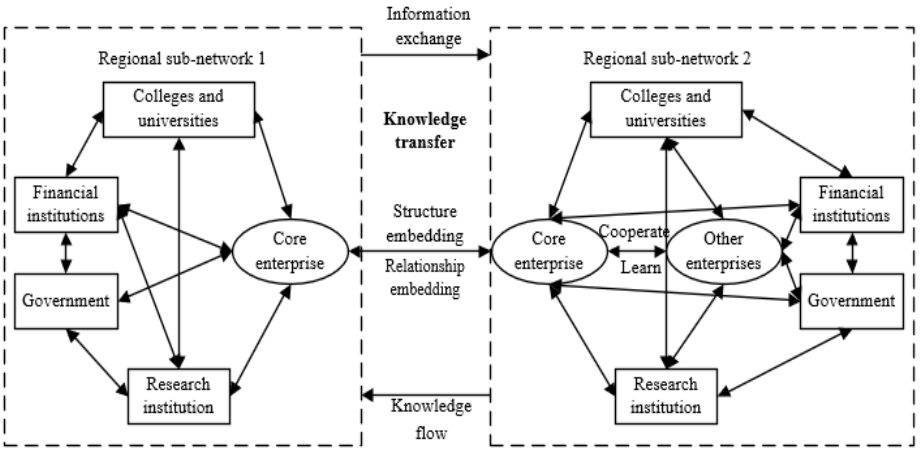

Figure 3. Collaborative innovation process of enterprises with different innovation abilities

Figure 3 gives the collaborative innovation process of enterprises with different innovation abilities. In the evolution equilibrium point of other enterprises that carry out collaborative innovation with an enterprise in the cluster, $b^*=0$ corresponds to the situation that enterprises in the cluster do not carry out collaborative innovation with those with a weaker collaborative innovation ability than themselves; $b^*=1$ corresponds to the situation that enterprises in the cluster would carry out collaborative innovation with those with a weaker collaborative innovation ability than themselves. Equilibrium point $a^*=r(y_2+d_2)/y_2(2r+u)=1/2+r/u(1+d_2/y_2)$ indicates that whether an enterprise in the cluster will choose to carry out collaborative innovation with those with a weaker collaborative innovation ability or not is affected by its innovation investment d^2 and its innovation benefit y_2. It is related to the ratio of its innovation requirement u to the innovation investment of other entities r.

When $u\leq r$, there is $a^*=1/2+u/r(1+d_2/y_2)\geq 1/3(1+d_2/y_2)$, it indicates that when the innovation investment provided by an enterprise to other enterprises in the cluster with a weaker collaborative innovation ability is greater than the collaborative innovation benefit requirement of the enterprise, the proportion of such enterprise choosing to carry out collaborative innovation is more than 1/3 times of $1+d_2/y_2$.When $u\geq r$, there is $a^*=1/2+u/r(1+d_2/y_2) \geq 1/3(1+d_2/y_2)$, it indicates that when the collaborative innovation benefit requirement of an enterprise is more significant than its innovation investment, lowering the collaborative innovation cost and increasing the benefit are conducive to promoting more entities to choose to carry out collaborative innovation with enterprises.

b represents the proportion of entities choosing to carry out collaborative innovation with other enterprises with a weaker collaborative innovation ability, and it satisfies $0\leq b\leq 1$, so the symbol of db/dp is only related to $[(2r+u)a-r]y_2-rd_2$. When $a^*=1/2+u/r(1+d_2/y_2)$, there is $db/dp=0$, the proportion of enterprises carrying out collaborative innovation with other entities will remain unchanged. When $a>1/2+u/r(1+d_2/y_2)$, there is $db/dp>0$, the proportion of enterprises carrying out collaborative innovation with other entities will increase. When $a<1/2+u/r(1+d_2/y_2)$, there is $db/dp<0$, the proportion of enterprises carrying out collaborative innovation with other entities will increase, ultimately, the collaborative innovation network of enterprises in the cluster will no longer exist.

With the evolution equilibrium points of entities, $a'=0$, $a^*=1$, $a^*=1/2+u/r(1+d_2/y_2)$, and $b^*=0$, $b^*=1$, $b^*=1/2+r/u(1+d_1/y_1)$ as boundaries, the strategy choices of enterprises in the cluster were divided into several intervals. For enterprises in different intervals, the evolution path directions of the collaborative innovation network are different.

Case 1: when $b>1/2+r/u(1+d_1/y_1)$ and $a>1/2+r/u(1+d_2/y_2)$, there are $da/dp>0$ and $db/dp>0$, in this interval, the collaborative innovation network of enterprises in the cluster has a good evolution path and the network scale will expand.

Case 2: when $b<1/2+r/u(1+d_1/y_1)$ and $a<1/2+r/u(1+d_2/y_2)$, there are $da/dp<0$ and $db/dp<0$, in this interval, the collaborative innovation network of enterprises in the cluster declines rapidly, and the network scale will shrink.

Case 3: when $b>1/2+r/u(1+d_1/y_1)$ and $a<1/2+r/u(1+d_2/y_2)$, there are $da/dp>0$ and $db/dp<0$, at this time, the proportion of enterprises willing to carry out collaborative innovation exceeds the equilibrium value, while the proportion of enterprises willing to carry out collaborative innovation with other entities with a weak collaborative innovation ability in the cluster will decline; in the end, it will reach a temporary equilibrium state at the point where $b=1/2+r/u(1+d_1/y_1)$ and $a=1/2+u/r(1+d_2/y_2)$.

Case 4: when $b<1/2+r/u(1+d_1/y_1)$ and $a>1/2+r/u(1+d_2/y_2)$, there are $da/dp<0$ and $db/dp>0$, at this time, under the influence of the high collaborative innovation willingness of enterprises with a weak innovation ability, the enthusiasm of other entities in the cluster for collaborative innovation will be improved to a certain extent, in the end, at the point where $b=1/2+r/u(1+d_1/y_1)$ and $x=1/2+r/u(1+d_2/y_2)$, it couldn't reach an equilibrium state.

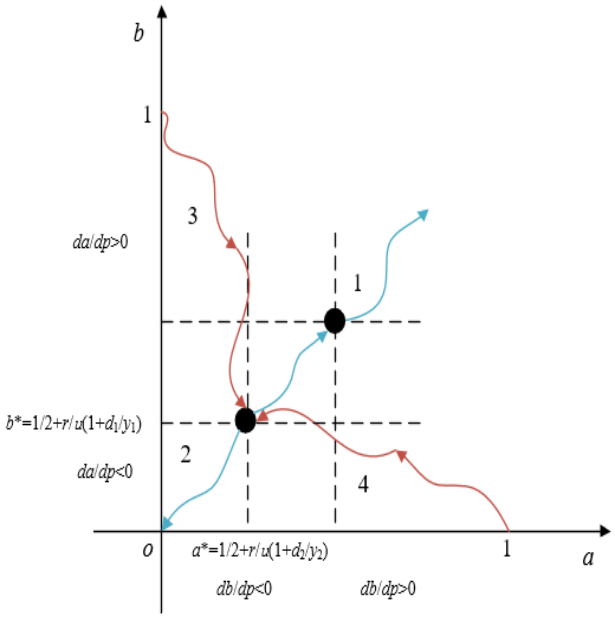

Figure 4. Evolution paths of collaborative innovation of enterprises in the cluster

Figure 4 depicts the evolution of collaborative innovation among the cluster's businesses. According to the figure, the decrease in innovation investment among collaborative

innovation participants has encouraged more businesses in the cluster to engage in collaborative innovation. The scope of the network for collaborative innovation will continue to expand, and the collaborative innovation path indicates that at this time, businesses will enter a favorable evolution path for collaborative innovation.

4. Analysis and Findings

All experimental data presented in the text originated from the experiment itself. Unlike the extant self-organization theory of synergetic, this study investigated the collaborative evolution of four fundamental capability dimensions within an enterprise. Figure 5 depicts the development trend of collaborative innovation network scale for various collaborative innovation effect coefficients. As depicted in the figure, the network scale exhibits S-shaped variations over time, and under the influence of various coefficients, the network scale tends toward a steady state. When the coefficient reaches a certain value, however, the network scale may be underdeveloped, which suggests that collaborative innovations that rely solely on a benefit-driven mechanism are unlikely to elicit an active response in the network.

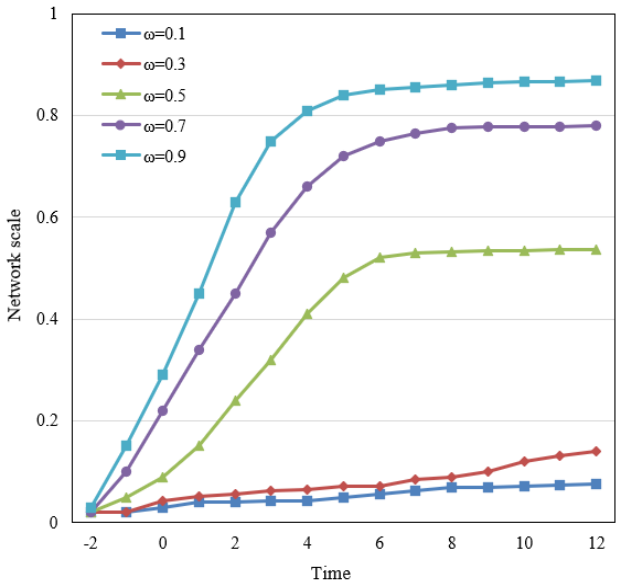

Figure 5. Trends of collaborative innovation network scale under different collaborative innovation effect coefficients

Figure 6 depicts the growth rate of collaborative innovation network scale for various collaborative innovation effect coefficients. As shown in the graph, when the coefficient is large, the development of network scale accelerates over time, reaches a zenith, and then declines to lower values at various levels. When the coefficient is small, the development of network scale climbs to a certain value and then tends to stabilize; under different coefficients of the collaborative innovation effect, the peak values the network scale reaches vary; the greater the coefficient, the higher the peak and the more pronounced the network scale changes. In addition, as the coefficient of the collaborative innovation effect increases, the horizontal coordinate of the network scale's apex shifts to the left, meaning that it takes less time to reach the peak.

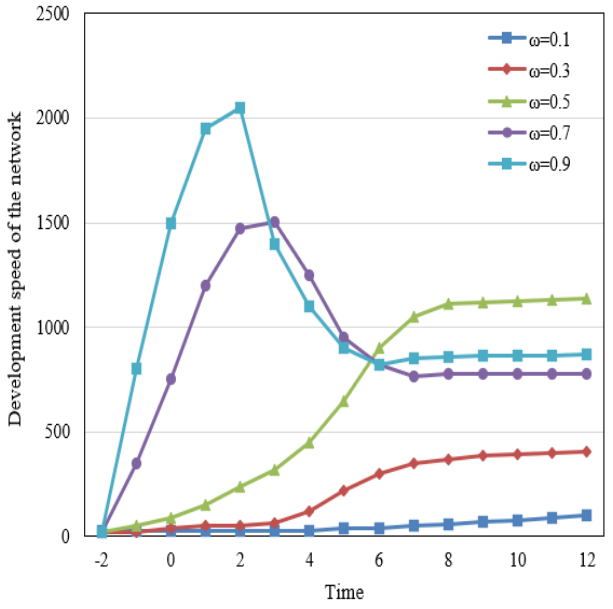

Figure 6. Development speed of collaborative innovation network scale under different coefficients of collaborative innovation effect

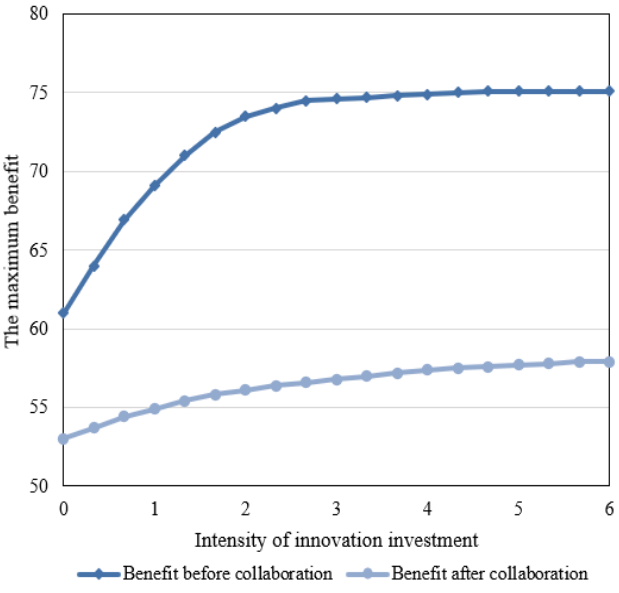

Figure 7. Effect of innovation investment intensity on the maximum benefit of enterprises

Figure 7 depicts the impact of innovation investment intensity on enterprises' maximal benefit. As shown in the graph, the maximal benefit of enterprises within the cluster increases as innovation investment intensity rises. Based on the increment of benefit, the benefit of enterprises prior to

collaborative innovation is greater than that of enterprises after collaborative innovation, indicating that the maximal benefit of collaborative innovation is more sensitive to changes in the innovation investment intensity. Figure 8 illustrates the impact of innovation investment intensity on cluster sales. According to the graph, as the intensity of innovation investment rises, the cluster's various entities, such as manufacturers and distributors, will reap greater benefits. The increase in innovation investment is conducive to increasing the benefit of entities in the upstream and downstream of the sports industry, as well as the influence on the sales profit of products from the cluster, judging by the benefit to the cluster's enterprises. Based on the total benefit of the cluster, an increase in innovation investment can result in an increase in innovation's total profit.

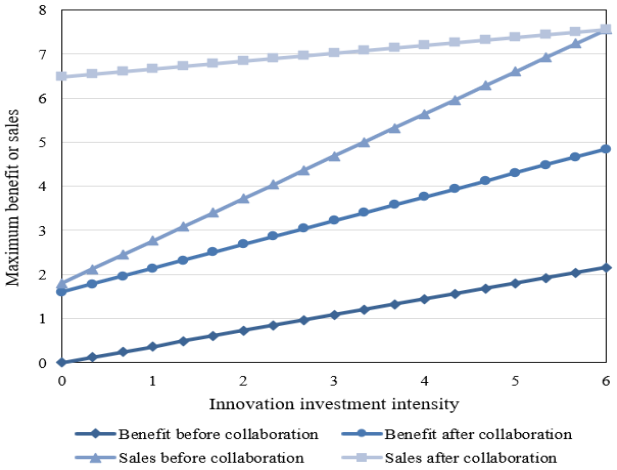

Figure 8. Effect of innovation investment intensity on the sales of the cluster

Table 1

Relevance between several entities and 11 subjects (other entities) in the regional collaborative innovation network

EN_i \ Subject	EN_1	EN_2	EN_3	EN_4	EN_5
SUB_1	0.807823	0.834576	0.772172	0.825335	0.7936
SUB_2	0.904281	0.895921	0.906753	0.845	0.884625
SUB_3	0.761845	0.7653	0.645344	0.6853	0.717535
SUB_4	0.854823	0.876954	0.875052	0.8421	0.827412
SUB_5	0.854665	0.851321	0.877589	0.809123	0.850631
SUB_6	0.829641	0.849543	0.877521	0.796053	0.828475
SUB_7	0.827859	0.813825	0.801243	0.788652	0.807443
SUB_8	0.756253	0.750132	0.715582	0.615912	0.7532
SUB_9	0.800342	0.789745	0.825271	0.753	0.778453
SUB_{10}	0.912934	0.827657	0.9352	0.910871	0.9092
SUB_{11}	0.865348	0.875033	0.8853	0.851322	0.839553

Case study is an important empirical research method that effectively illustrates the dynamic development process of example cases; thus, case study was utilized to analyze the collaborative innovation networks of small and medium-sized enterprises in two clusters. Table 1 demonstrates the importance of five entities and eleven subjects (other entities in the cluster) to the regional collaborative innovation network. According to the data in the table, regardless of how the relevance between entities in the cluster and other subjects with a weaker innovation ability is evaluated, or how the level of collaborative innovation effect of different regional sub-networks is evaluated, there are certain differences in the relevance values of the collaborative innovation relationship, but the overall fluctuations are not statistically significant, indicating that there is no sudden change in the intention of e-innovation. In order to illustrate the relevance of other disciplines to the regional collaborative innovation network, Figure 9 provides a diagram of relevance degree values. According to the classification criteria for relevance, it is known that there is significant relevance between the regional collaborative innovation network and eleven other resource-type topics.

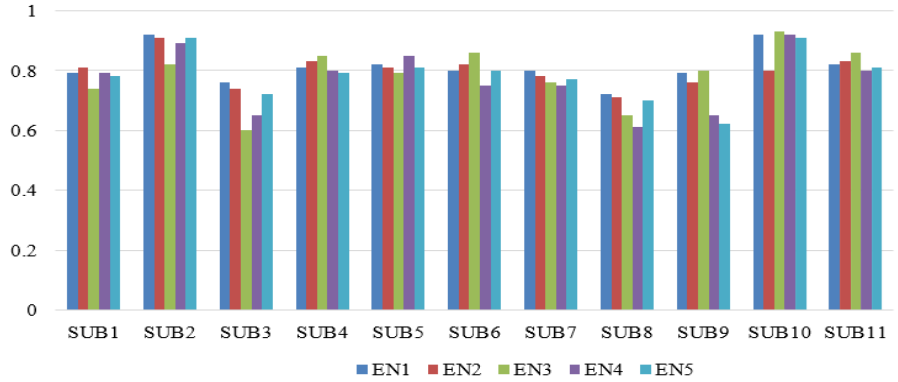

Figure 9. Relevance between 11 subjects and the regional collaborative innovation network

5. Conclusion

This study examined the evolution of multi-entity collaborative innovation of complex network-based sports industry clusters. Initially, the process of multi-entity collaborative innovation of sports industry cluster was analyzed, along with the model's fundamental hypotheses and the conditions for the formation of cluster collaborative innovation. Then, this study deepened the analysis of the evolution mechanism of the enterprise cluster's collaborative innovation network. Combining experimental results, this study determined the trend and speed of the development of a collaborative innovation network under varying coefficients of collaborative innovation effect, as well as the impact of innovation investment intensity on the maximum benefit to enterprises and the size of the cluster. This study concluded with a summary of the relevance values of several entities in relation to other topics and the regional collaborative innovation network, as well as the relevant analysis conclusions.

By forming relationships within the collaborative innovation network, small and medium-sized businesses in the cluster can effectively procure complementary resources and avoid disadvantages such as a lack of risk resistance or a deficiency in key technologies. By employing the replication dynamic model in evolutionary game theory to analyze the evolution of collaborative innovation networks, the connection between individual centrality networks and the overall centrality network in network research could be effectively resolved, and the synergy between the two parties in the network relationship could be analyzed. This study does not elaborate on the differences in group decision-making caused by the characteristics of each entity type. Therefore, in future research, we will enrich and modify this content so that research theories better reflect the reality in cluster economic activities and provide better guidance for the innovation and expansion of small and medium-sized businesses.

6. Theoretical and Practical Implications

This study has presented new findings regarding the cluster-based market diversification required to enhance the performance of the sports industry. Existing studies have not discussed all of these dimensions for new types of sports networks and markets, as demonstrated by the findings of this study. The findings of this research, which are crucial to enhancing the scholars' comprehension, allow for the development of a deeper understanding. In addition, the findings of this study have introduced the cluster-based division of small and medium-sized businesses into the literature, which has not been thoroughly discussed in previous studies on sports performance and industry.

The findings of this research have practical significance because this research introduces a new perspective on these findings. However, the research has revealed that innovations in the cluster-based sports industry may have new market access strategies. When the product is brand-new to the market and there are no restrictions on the product, the marketing strategy can be successful. However, product performance can be successful if an appropriate market target is established. Therefore, cluster-based working and networks for product innovation and performance can enhance the sports industry's productive operations. These findings can be implemented practically in any region.

7. Future Directions

The Likert scale questionnaire should be used to capture data from respondents for these future studies. The Likert scale questionnaire is used to collect reflective measurement-based quantitative data. In addition, the findings of this study should be expanded upon by developing multigroup-based data analysis using cluster-based data collection. Consequently, it is desired that future research examine the impact of sports marketing on the performance of the sports industry with the moderating influence of consumer awareness. In addition, scholars are encouraged to examine the effect of marketing performance on the performance of the sports industry through the mediation of price control. Consequently, these findings would contribute to the body of knowledge with significant findings.

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