Dynamic Evolution of Technological Innovation Capability of High - tech Shipbuilding Industry

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Abstract. Improving the technological innovation ability of high-tech shipbuilding industry helps to improve the overall innovation level of China 's shipbuilding industry and promote the high-quality development of the national economy. Based on the perspective of complex adaptive system theory, the dynamic evolution model of technological innovation capability of high-tech shipbuilding industry is constructed from the dimensions of industrial technological innovation process and industrial technological innovation practice. The genetic algorithm is introduced to solve the model, and the simulation analysis is completed the characteristics of high-tech ship industry in China. It is found that collaborative innovation has a certain role in promoting the technological innovation capability of high-tech shipbuilding industry. Resource aggregation ability and absorptive capacity have played a significant constraint role in the evolution process of industrial technological innovation capability. Simply increasing investment does not necessarily improve the technological innovation capability of high-tech shipbuilding industry. Based on the current situation of technological innovation of high-tech shipbuilding industry in China, this paper puts forward some management countermeasures to improve the technological innovation ability of high-tech shipbuilding industry in China.

Keywords: High-tech shipbuilding industry; technological innovation capability; evolution; genetic algorithm

1 Introduction

China has become one of the world's major shipbuilding countries, but the shipbuilding industry is still in a large but not strong state, and the overall technological innovation capability is still at a low level, especially in the high-tech shipbuilding industry. Meanwhile, With the interweaving of the new scientific and technological revolution, the industrial revolution and the military revolution, the ability of technological innovation has increasingly demonstrated the level of competition in comprehensive national strength. As a high-end industry in the value chain of the shipbuilding industry, it is of great practical significance to study the dynamic evolution of its technological

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innovation capability for promoting the transformation and upgrading of the shipbuilding industry and improving the core competitiveness of China 's high-tech shipbuilding industry so as to realize the shipbuilding power.

2 Literature Review

At present, the research on technological innovation ability at home and abroad has been very rich, mainly focusing on definition[1], influencing factors[2], evaluation[3] and so on. However, with the deepening of research, some scholars have pointed out that the technological innovation is a self-organizing system with nonlinear characteristics, and advocate expanding the research on technological innovation capability from a dynamic perspective. Su et al.[4]pointed out through a longitudinal multi-case study that in the context of supply chain integration, the technological innovation capability of small and medium-sized manufacturing enterprises shows an evolutionary trend from low-level to high-level, and follows the path of " local-customization-coordination. " Through the case analysis of Huawei, Liu and Yang [5]found that the innovation ability of latecomer high-tech enterprises evolved along the track of resource construction-resource bricolage-resource integration-resource governance ability in the development process of primary production stage, internationalization development stage, globalization expansion stage and innovation leading stage.

Through combing the relevant literature on technological innovation capability, it is found that the existing research mostly explores the influencing factors and evaluation indicators of technological innovation capability from a static perspective. There are relatively few literatures describing the evolution process of technological innovation capability from a dynamic perspective, and the research objects focus on high-tech industries and enterprises, lack of specific industrial situations. At the same time, the research methods are mostly case analysis, and there are few literatures using simulation models. Therefore, based on the theory of complex adaptive system, this paper constructs the technological innovation system of high-tech shipbuilding industry, establishes the dynamic evolution model of technological innovation ability of high-tech shipbuilding industry from the dimension of industrial technological innovation process and industrial technological innovation practice, uses genetic algorithm and MATLAB to carry out simulation research, and explores how technological innovation process and practice promote the dynamic evolution of technological innovation ability of high-tech shipbuilding industry, clarifies the key factors affecting the technological innovation ability of high-tech shipbuilding industry, so as to improve the innovation efficiency of high-tech shipbuilding industry and improve the core competitiveness of high-tech shipbuilding industry.

3 Research on the dynamic evolution process of technological innovation capability of high-tech shipbuilding industry

3.1 Conceptual model of technological innovation system of high-tech shipbuilding industry

The complex adaptive system (CAS) theory was proposed by Professor John Holland in 1994. The theory believes that the power of system evolution mainly comes from the internal system, that is, the interaction between micro-subjects produces macro-complex phenomena. The core of its modeling is to explore how local transmutation highlights integrity through positive feedback and adjustment. Complex adaptive system is considered to be a system composed of rule description and interactive adaptive agents, with four characteristics of aggregation, nonlinearity, flow and diversity.

Based on the theory of complex adaptive system, the technological innovation system of high-tech shipbuilding industry is reconstructed from the perspective of innovation environment and innovation subject. The conceptual model is shown in Figure 1. Under the stimulation of the innovation environment, the innovation subject will adopt some form of cooperation to gather and form two main system levels, namely the core layer and the auxiliary layer. The core layer includes high-tech shipbuilding enterprises, supporting enterprises, scientific research institutes and universities. Among them, high-tech shipbuilding enterprises cover leading enterprises and satellite enterprises. Generally speaking, the high-tech shipbuilding industry is dominated by leading enterprises with strong market competitiveness in high-tech shipbuilding enterprises, and cooperates with scientific research institutes, universities and supporting enterprises to innovate and provide technical and financial support; the auxiliary layer is composed of financial institutions, governments and shipbuilding industry associations. It plays the role of supporter and coordinator in the system and plays an important role in supporting the core layer. The process of industrial technological innovation reflects the characteristics of ' flow ' in the complex adaptive system, reflecting the transfer and transmission of information, capital and other resources in the technological innovation system of high-tech shipbuilding industry, while the practice of technological innovation shows the rules and codes of conduct to be followed by the adaptive subjects within the system.

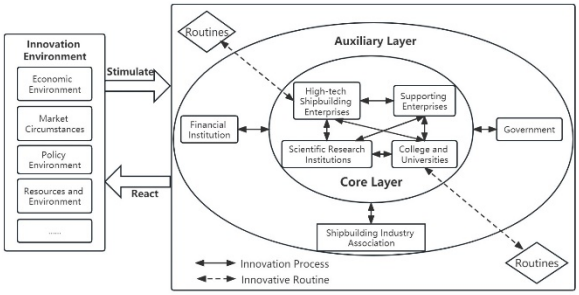

Fig. 1. Conceptual model of technological innovation system of high-tech shipbuilding industry

3.2 Dynamic evolution process of technological innovation capability of high-tech shipbuilding industry

Referring to the research results of Huo et al.[6], from the perspective of industrial technology innovation process and industrial technology innovation practice, the technological innovation capability of high-tech shipbuilding industry is defined as: under the constraints of dynamic complex environment and industrial technology innovation practice, through the high-tech shipbuilding industry. The existing resources and external resources are re-integrated and configured, coordinated R & D, commercialization of R & D results and other industrial technology innovation processes, the system presents integrity, and an ability of industrial technology innovation results or innovation performance emerges.

Based on the theory of complex adaptive system, the technological innovation system of high-tech shipbuilding industry will make a certain response behavior under the stimulation of external dynamic environment. At the same time, under the constraints and guidance of technological innovation practices, the existing technological innovation process is rectified and optimized, so that the system presents integrity and continuously stimulates technological innovation capabilities. The integration and optimization of the technological innovation system of high-tech shipbuilding industry reflects the optimization of the technological innovation process of high-tech shipbuilding industry, and the optimization of the technological innovation process is restricted and supervised by the technological innovation practice. The specific evolution process is shown in Figure 2.

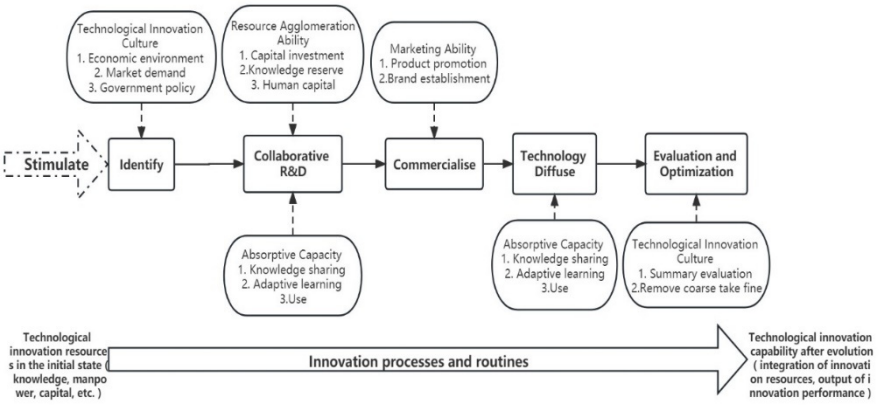

Fig. 2. Dynamic evolution process of technological innovation capability of high-tech shipbuilding industry

3.2.1 Industrial technology innovation process

During the operation of the technological innovation system of high-tech shipbuilding industry, the interaction between the subjects follows a certain technological innovation process, which can be divided into identification,

collaborative research and development, commercialization, technology diffusion and evaluation optimization.

(1) Identification

Identification refers to the accurate identification of the dynamic environment of each adaptive subject in the technological innovation system of high-tech shipbuilding industry, including the excavation of market demand and the development trend of macro economy. Each adaptive subject will analyze its own resources and knowledge reserves according to the characteristics of the environment, and determine the development direction.

(2) Collaborative R & D

Collaborative R & D refers to the process of establishing R & D cooperation relations among adaptive subjects in order to achieve their own development goals. In the high-tech ship industry technology innovation system, in order to design and manufacture high-tech ships with market competitiveness and obtain more profits, each adaptive subject chooses collaborative research and development to gather the required resources.

(3) Commercialization

Commercialization refers to the process in which the subject applies and pushes to the market after completing the R & D goal and obtaining the R & D results, mainly including patent application, manufacturing, brand building, promotion and marketing. Generally speaking, this stage is constrained by market demand and marketing ability.

(4) Technology diffusion

Technology diffusion process refers to the process of transferring and diffusing R & D patents in the industry in order to improve the knowledge level and technological innovation ability of the whole high-tech shipbuilding industry. Through knowledge sharing, adaptive learning and utilization, more innovations burst out on the basis of original innovation.

(5) Evaluation optimization

Evaluation optimization refers to the behavior of high-tech shipbuilding industry technology innovation system to evaluate its own technological innovation process and routine operation status. Strengthen the proven effective technological innovation processes and practices, eliminate backward and outdated parts, and explore new rules to optimize the entire system, so as to enhance the technological innovation capability of the high-tech shipbuilding industry.

3.2.2 Industrial technology innovation practices

In the technological innovation system of high-tech shipbuilding industry, each adaptive subject needs to follow certain technological innovation practices according to the dynamic and complex environment, that is, the basic code of conduct of technological innovation activities, and then guide and coordinate the operation of the entire industrial technological innovation process. Technological innovation practices generally include: technological innovation culture, resource agglomeration ability, absorptive capacity, marketing ability.

(1) Technological innovation culture

Technological innovation culture is the premise of technological innovation activities. The R & D cooperation, knowledge sharing, resource diffusion and other behaviors of each adaptive subject in the technological innovation system of high-tech shipbuilding industry must be carried out around the technological innovation culture. Generally speaking, the construction of industrial technology innovation culture needs to be carried out according to the characteristics of external environment. The national industrial policy, support, regional human capital advantages and market development trend are expected to have an immeasurable impact on the operation direction and innovation performance of the technological innovation capability system of high-tech shipbuilding industry for a long period of time.

(2) Resource agglomeration ability

The ability of resource agglomeration refers to the ability to integrate and utilize resources such as internal and external funds, talents and raw materials of the existing high-tech shipbuilding industry, so as to ensure the healthy operation and effective development of the entire high-tech shipbuilding industry chain. The ability of resource agglomeration is mainly affected by the culture of technological innovation and regional talent policy. It is an important way to promote the high-tech shipbuilding industry to internalize external resources and increase the internal knowledge reserve of the industry to obtain more R & D patent results.

(3) Absorptive capacity

Absorptive capacity was first proposed by Cohen et al. and defined as the ability of enterprises to combine new knowledge acquired with existing resources and apply it. Based on this, this paper believes that absorptive capacity refers to the ability of adaptive learning guided by knowledge sharing within the technological innovation system of high-tech shipbuilding industry and using knowledge to produce innovative results. Knowledge sharing reflects the collaboration between the various subjects to ensure the smooth flow of information resources ; adaptive learning reflects the efficiency of each subject to absorb external information ; and finally through the use of stage to reflect the industrial technology innovation achievements and innovation performance.

(4) Marketing ability

At present, the academic community has not yet formed a definition of marketing capabilities. This paper argues that marketing ability refers to the ability of high-tech shipbuilding industry to bring technological innovation achievements to the market and build its own brand. In general, the concentration of China 's shipbuilding industry is significantly lower than that of Japan and South Korea. There is no unified brand identity and lack of brand competitiveness in the world. To a certain extent, enhancing marketing ability and creating independent brands will help high-tech shipbuilding enterprises to build corporate image, increase market share, and enhance international competitiveness and discourse power.

4 Construction and analysis of dynamic evolution model of technological innovation capability of high-tech shipbuilding industry based on genetic algorithm

4.1 Dynamic evolution model of technological innovation capability of high-tech shipbuilding industry based on genetic algorithm

In the technological innovation system of high-tech shipbuilding industry, a series of adaptive behaviors and evolution of the system are finally manifested as the change of industrial technological innovation ability, that is, the change of technological innovation ability intensity of high-tech shipbuilding industry. With the help of the biological evolution principle of genetic algorithm, it will be more helpful to clearly describe the evolution process of complex adaptive system. As the key to the process of industrial technology innovation, collaborative innovation is the prerequisite for commercialization and industrial technology diffusion. At the same time, resource agglomeration ability and absorptive capacity constraints affect the final innovation results of collaborative innovation. Therefore, the industrial innovation process of ' collaborative innovation ' and the two industrial technology innovation practices of ' resource agglomeration ability ' and ' absorptive capacity ' are selected to construct the fitness function of the dynamic evolution of the technological innovation capability of the high-tech shipbuilding industry, as follows (The parameter interpretation is shown in Table 1):

$$max\ y_1=x_4/(x_1+x_2) \tag{1}$$

$$max\ y_2=k_1*(x_1+x_2+x_3+x_5) \tag{2}$$

$$max\ y_3=k_2*(x_2+x_3) \tag{3}$$

$$\max y_4=k_2*e^{x_2} \tag{4}$$

Table 1. Parameters' symbol descriptions

x_1	Capital input	Values range
x_2	Knowledge stock	[1,5]
x_3	R&D personnel investment	[1,5]
x_4	Industrial technology innovation achievements	[1,5]
x_5	The frequency of communication organized to promote the flow of knowledge among innovation subjects	[1,5]
k_1	The low strength of the network relationship between the subjects leads to the probability of poor communication, so the resource agglomeration ability is limited.	[0,1]

k_2	Due to the high complexity of knowledge and the possibility of low efficiency of external knowledge internalization caused by low quality of R & D personnel and poor knowledge potential within the system of technological innovation capability of high-tech shipbuilding industry, the absorptive capacity is limited.	[0,1]

The fitness function of the dynamic evolution of technological innovation capability of high-tech shipbuilding industry constructed by the dimensions of ' collaborative innovation ', ' resource agglomeration ability ' and ' absorptive capacity ' is a multi-objective function. In this model, the formula (1) represents the input-output ratio of the high-tech shipbuilding industry technology innovation system to maximize the pursuit, reflecting the technological innovation capability ; type (2) indicates that in order to gather more resources, R & D activities can be effectively carried out and organize as many communication seminars as possible ; type (3) indicates that the R & D subjects within the high-tech shipbuilding industry technology innovation system expect knowledge to be efficiently utilized to produce innovative results with core competitiveness ; the formula (4) indicates that the subjects within the system conduct adaptive learning on the basis of the existing knowledge stock, and constantly generate and accumulate new knowledge.

4.2 Model solving

When using genetic algorithm to deal with multi-objective function optimization problems, it is generally necessary to convert the objective function into a vector minimization form. The conversion results are as follows.

$$min\, y_1 = -x_4 \,/\, (x_1 + x_3) \tag{5}$$
$$min\, y_2 = -k_1 * (x_1 + x_2 + x_3 + x_5) \tag{6}$$
$$min\, y_3 = -k_2 * (x_2 + x_3) \tag{7}$$
$$min\, y_4 = -k_2 * e^{x_2} \tag{8}$$
$$S.\ T.\ \ x_1, x_2, x_3, x_4, x_5 \in [1,5]$$

In the multi-objective function optimization problem, there is no definite solution that can make the sub-objective set reach the best state. Therefore, the solution in the multi-objective function optimization is a compromise value, which can make the objective function obtain the maximum relative optimal solution, also known as the Pareto optimal solution. There are five methods to solve the genetic algorithm. The most common method is the weight coefficient method. However, due to the need to use expert scoring to give the weight of each sub-objective, with a certain subjective color, this paper adopts a more efficient genetic algorithm-NSGA-II in the calculation process[7].

4.3 Analysis of simulation results

Before using MATLAB for simulation, we first need to set reasonable initial parameters. According to the actual situation, the population size M is set to 50, the crossover probability $Pc = 0.6$, the mutation probability $Pm = 0.1$, $k1$ and $k2$ take 0.5, and iterate 100 times, 200 times, 300 times and 500 times respectively. The Pareto frontier graph is obtained, as shown in Figure 3-6.

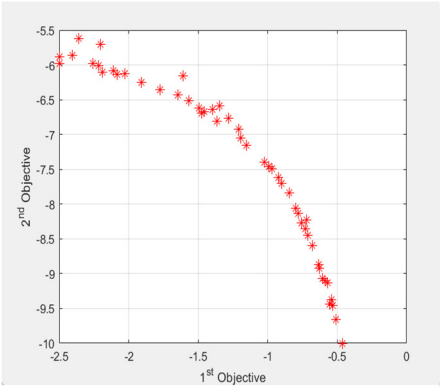

Fig. 3. Pareto frontier graph of 100 iterations

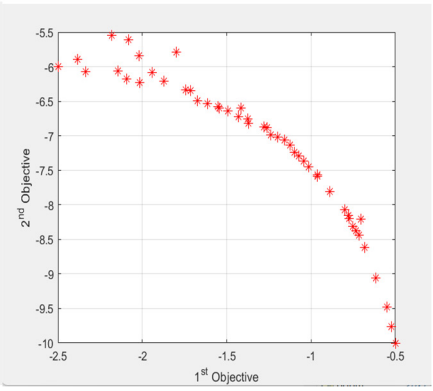

Fig.4 Pareto frontier graph of 200 iterations

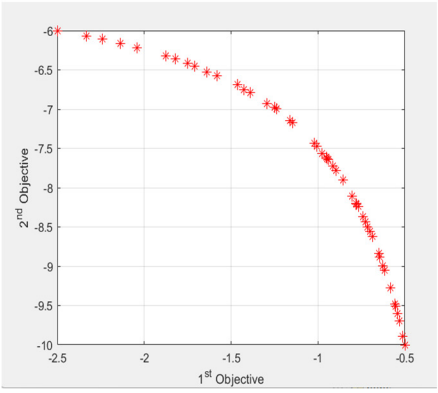

Fig. 5. Pareto frontier graph of 300 iterations

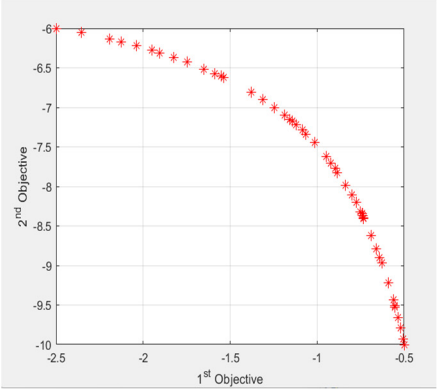

Fig.6 Pareto frontier graph with 500 iterations

In order to further obtain better iterative results, the obtained data are statistically described and analyzed by SPSS software, and the group with the smallest standard error is selected. After sorting, table 2 and table 3 are obtained.

Table 2. Each variable value corresponding to the function value after iteration

	x_1	x_2	x_3	x_4	x_5
Iteration 100 times	1.9237	4.9227	2.5665	4.9451	4.9771

Iteration 200 times	1.8707	4.8938	4.5428	5	4.8973
Iteration 300 times	2.1826	4.9432	4.8002	5	5
Iteration 500 times	1.9257	4.9454	4.8372	5	5

Table 3. The absolute value of each function value after iteration

	y_1	y_2	y_3	y_4
Iteration 100 times	0.9007	7.705	4.2446	68.6851
Iteration 200 times	0.7796	8.1023	4.7183	66.7302
Iteration 300 times	0.7160	8.463	4.8717	70.1098
Iteration 500 times	0.7393	8.3541	4.8913	70.264

Through the analysis of the data obtained, it can be concluded that:

(1) As a key path of technological innovation process, ' collaborative innovation ' has a significant role in promoting the technological innovation capability of high-tech shipbuilding industry. It can be seen from Table 2 that the industrial innovation achievement x_4 increases with the increase of the number of iterations until it reaches the threshold, indicating that with the strengthening of collaborative innovation, the technological innovation ability of high-tech shipbuilding industry is constantly improving. At the same time, according to the numerical change trend of capital input x_1 and y_1, the input-output ratio is decreasing, indicating that the system evolution has its internal evolution mechanism, and it is not possible to increase the investment to improve the technological innovation ability of the whole industry.

(2) The two industrial technological innovation practices of ' resource agglomeration ability ' and ' absorptive capacity ' play an obvious restrictive role in the technological innovation system of high-tech shipbuilding industry. In Table 2, the knowledge stock x_2 and R & D personnel input x_3 do not increase with the number of iterations, but gradually tend to a certain value, reflecting the constraint effect of industrial technology innovation practices.

(3) Due to the interaction between the adaptive subjects in the process of integrating the industrial technological innovation process, the industrial technological innovation routines have undergone different degrees of recombination and variation on the basis of heredity, and then evolved, finally manifested as the break of the original path and the evolution of the whole system, and a certain degree of technological innovation routines can make the subjects within the system reach a consensus and promote the formation of knowledge spillover effect[8]. From Table 2, it can be seen that the industrial innovation achievement x_4 and the frequency of communication and discussion to promote knowledge flow x_5 have reached the upper limit of the threshold value when iterating to a certain extent, indicating that under the influence of industrial technology innovation practices, technology spillover effect and knowledge spillover effect have occurred in the technological innovation system of high-tech shipbuilding industry. These technologies and knowledge are constantly transferred and circulated in the system, and are accepted and absorbed by satellite enterprises and supporting enterprises to form knowledge reverse spillover effect, thus increasing the amount of knowledge in the whole system, that is, the rise of y_4 value.

5 Conclusion and Implications

Combined with the current situation of China's high-tech shipbuilding industry and simulation analysis, the conclusions and management implications are as follows.

(1) The evolution process of high-tech shipbuilding industry technology innovation system is based on the stimulation of high-tech shipbuilding enterprises, research institutes, universities and other adaptive subjects to receive external dynamic and complex environmental information, and then constantly adjust the industrial technology innovation process and industrial technology innovation practice, so as to coordinate the operation, and finally continue to emerge technological innovation ability.

(2) Collaborative innovation can significantly promote the improvement of technological innovation ability, and blindly increasing innovation investment will not continue to bring positive effects to technological innovation ability. The overall concentration of China 's high-tech shipbuilding industry is low, which leads to the cooperation is weak and the underutilization of innovation resources. Therefore, we should pay attention to the development of innovation network, fully mobilize the advantages of each subject, gather innovation resources and rationally allocate them, so as to make the best use of them.

(3) The practice of industrial technological innovation has a restraining effect on the evolution process of technological innovation in high-tech shipbuilding industry, and along with the reorganization and variation, it presents the break of the original path and the evolution of the whole system. China 's high-tech shipbuilding industry has the problems of shortage of technical talents, asymmetry of knowledge and information, and low innovation efficiency. Therefore, it is necessary to reasonably formulate industrial technology innovation practices and play their role. A certain degree of practice can realize the frequent and smooth transfer of knowledge within the system. However, with the further improvement of technological innovation practices, it may limit the reconstruction of the cooperative relationship of innovation subjects, resulting in fewer and fewer alternative action opportunities, and even conflicting behavior, thus reducing cooperation and inhibiting the formation of reverse knowledge spillover effect.

References

1. Wei, J., Han, W. Definition of Enterprise Technological Innovation Capability and Its Relationship with Core Competence [J]. Science Research Management, 1998(06):13-18.
2. Li, Z., Ou, G. J., & Liu, S. L. Research on the Identification and Optimization of the Factors Influencing the Disruptive Technological Innovation Ability of High-tech Enterprises-Based on the perspective of innnovation ecosystem[J]. Technology and Innovation Management, 2021,42(01):20-28.
3. Yan, Q., Hou, R. Y.. Evaluation of Regional Scientific and Technological Innovation Capability and Empirical Research[J]. Agro Industry Hi-Tech, 2017,28(1):3179-3181.

4. Su, J. Q., Ma, H. H., & Shuai, Z. The research of evolution mechanism of technological innovation capability of small and medium-sized manufacturing enterprises[J]. Studies in Science of Science, 2020,38(10):1888-1898.
5. Liu, H. B.,Yang, L. The evolution law and promotion mechanism of the innovation capability of latecomer high-tech enterprises[J]. Science Research Management, 2022,43(11):111-123.
6. Huo, C. B., Han, Z., & Ke, X.. Research on the Technology Innovation System of BioPharmaceutical Industry by Using Genetic Algorithm[J]. Science and Technology Management Research, 2017,37(06):118-126.
7. Ren, W. J.. Research on Technological Innovation Capability System of Non-ferrous Metal New Material Industry by Using Genetic Algorithm[D]. Journal of Kunming University of Science and Technology, 2018.
8. Li, T., Zhang, Z. Y., & Zheng, F.. Innovation Ecosystem: Knowledge Integration Capability and Reverse Knowledge Spillover Effect[J]. Enterprise Economy, 2022,41(07):42-55