

# Research on the Symbiotic Evolution of Subjects in Emerging Technology Innovation Ecosystem

Hong Liu

School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing, 400065, China

**Abstract:** Innovation ecosystem is an important way for emerging industries to integrate innovation resources and enhance the core competitiveness of industries. Based on the perspective of system symbiotic evolution research, this paper uses the Logistic equation of ecology to construct a symbiotic evolution model of emerging technological innovation ecosystems, analyzes the equilibrium points and equilibrium conditions of system evolution, and reveals the symbiotic evolution laws of emerging technological innovation ecosystems. The results show that: (1) The emerging technology innovation ecosystem is a complex system in which four types of innovation subjects, namely the core innovation layer, auxiliary innovation layer, supporting innovation layer, and application innovation layer, jointly create value in a certain symbiotic environment; (2) Innovation subjects The degree of symbiosis between them determines the stability and equilibrium state of the symbiotic evolution of the emerging technological innovation ecosystem; (3) The mutual-benefit symbiosis model can maximize the synergy of innovation subjects, and system members should strive to change from the parasitic symbiosis to the beneficial symbiosis. Switch to symbiosis mode.

**Keywords:** Emerging technologies, Innovation ecosystem, Symbiotic evolution.

## 1. Introduction

In recent years, emerging technologies with disruptive characteristics represented by big data, blockchain, artificial intelligence, etc. have emerged continuously. Emerging technologies have become the strategic commanding heights and main directions for countries around the world to seize development opportunities in the new round of industrial revolution. Emerging technologies are characterized by high uncertainty, creative destruction, and “winner takes all” [1], and its development can not only trigger the creation of a new industry, but also lead to drastic changes in a traditional industry Even disappear [2]. In addition to the support provided by science and technology and underlying architecture, the development of emerging technologies also requires a good enterprise development environment and a complete industrial supporting and supporting system [3]. With the rapid development of a new round of emerging technologies and emerging industrial revolutions, the boundaries between innovation subjects have become increasingly blurred, and the innovation ecosystem of multi-subject collaborative interaction has become a new paradigm for value creation research [4]. The application and scenario-based layout of emerging technologies cannot be effectively implemented only by the development of a single enterprise. It must be promoted through resource sharing and business cooperation between innovation entities in the system [5] Value co-creation is the core driving force to promote the evolution and development of emerging technology innovation ecosystems. Therefore, the symbiotic evolution of emerging technological innovation ecosystems based on value co-creation has become an important direction of academic research.

Focusing on emerging technology fields, scholars are still in their infancy in the research on the symbiosis of emerging technology innovation ecosystems [6-7]. The evolution process of the emerging technology innovation ecosystem is a dynamic reflection of the competition and cooperation

among the participants in the system [8]. In recent years, scholars have mainly conducted research on the evolution mechanism and evolution path of the innovation ecosystem of emerging industries from the perspectives of competition and collaboration. On the one hand, various participants in the system cooperate with each other [9], break the boundaries of knowledge and resources [10], and continuously integrate and share internal and external innovation resources [11], maintain the healthy operation of the entire innovation ecosystem while achieving its own independent development [12], and promote the evolution of the innovation ecosystem to a deeper level [13]. On the other hand, there are also problems such as mutual competition and resource contention among the participating subjects [14], and the relationship among members of the innovation ecosystem is affected and restricted by various factors. The dominant position of core enterprises in the innovation ecosystem will be threatened with the increase of innovation resources and scale expansion of upstream and downstream enterprises [15], thus affecting the overall evolution effect of the system [16]. With the development of emerging technologies, the boundaries between organizations are becoming more and more blurred, and value co-creation activities no longer focus on a single value chain, but gradually expand to multiple value networks [17]. There are more complex and dynamically coupled network interaction relationships between innovation subjects [18], and the value acquisition and coordination of competition and synergistic relations among various participants in the system are crucial to the orderly evolution of the ecosystem. important. Therefore, comprehensively considering the impact of appropriate competition mechanism and synergy methods such as resource integration, sharing, and innovation interaction on the realization of value co-creation [19], it has become important to discuss the development dynamic mechanism and evolution law of my country's emerging technological innovation ecosystem. The essential.

The current research results have laid a theoretical

foundation and provided a new research perspective for exploring the emerging technological innovation ecosystem, but the existing research still has the following deficiencies: (1) Although relevant scholars have begun to use the ecosystem perspective to study the relationship between the cultivation of emerging industries and development, but most studies only focus on system and mechanism construction and analysis of related influencing factors [11-12], lack of analysis of emerging technological breakthroughs and industrial transformation from the perspective of ecological evolution, and no clear emerging technological innovation ecosystem. It is difficult to guide relevant industries to make reasonable strategic planning and arrangements under the rapid development of emerging technologies; (2) Value co-creation, as the direct cause of the maintenance and development of emerging technology innovation ecosystems, can clarify the ecosystem. However, the existing research lacks the problem of exploring the symbiotic evolution of emerging technological innovation ecosystems from the perspective of value co-creation. Based on this, on the basis of clarifying the composition of the innovation subject of the emerging technology innovation ecosystem, this study uses the extended Logistic equation to establish a symbiotic evolution model of the emerging technology innovation ecosystem, and clarifies the final evolution direction of the emerging technology innovation ecosystem. The improvement of technology and the integration and development of innovation subjects in the emerging technology innovation ecosystem provide theoretical support and policy inspiration.

## **2. Composition Analysis of Emerging Technology Innovation Ecosystem**

According to the importance of the innovation subject in the emerging technological innovation ecosystem, the technological innovation function undertaken in the process of technological innovation, and the division of the structure of the emerging industry innovation ecosystem by previous scholars [20], the emerging technology innovation ecosystem is defined as the emerging technology-based, enterprise, government, and market as the main body of collaboration, surrounded by four types of innovation bodies in a certain symbiotic environment: the core innovation layer, the auxiliary innovation layer, the supporting innovation layer, and the application innovation layer. A complex system in which value capture and innovation interact to create value synergistically. Among them, the core innovation layer is the core enterprises, competitors, complementary enterprises, suppliers, etc. in the emerging technology innovation ecosystem, and it is the enterprise or organization that condenses the service value in terms of product production and use performance. The auxiliary innovation layer is knowledge-intensive or technology-intensive units with strong technological innovation capabilities, such as universities and research institutes, whose role is to fill the knowledge gap or market opening window. The supporting innovation layer is a government or financial institution that provides preferential policies or financial support in the emerging technology innovation ecosystem, and is the key support for system value creation. The application innovation layer refers to groups such as customers and end users in the emerging technology innovation ecosystem, which is the ultimate flow of value conversion. In the emerging technology innovation ecosystem, under the action of the

common goal and innovation environment, each innovation subject forms a symbiotic effect around resource sharing and knowledge interaction, continuously creates profits and values, and makes the system evolve towards a high-level symbiotic evolution [21].

## **3. Emerging Technology Innovation Ecosystem Symbiotic Evolution Model**

### **3.1. Conceptual Model of Emerging Technology Innovation Ecosystem**

Symbiosis theory holds that a complete ecosystem is composed of three elements: symbiotic unit, symbiotic model, and symbiotic environment, all of which interact and are indispensable [22]. Among them, the symbiotic unit is the basis for the existence of the ecosystem; the symbiosis model is the form of evolution and development among innovative subjects; the symbiosis environment is the support and guarantee for the good operation of the ecosystem. The innovation subjects of the emerging technology innovation ecosystem are in different ecological niches. By providing unique and specialized products or services, they can expand and optimize their respective ecological niches, strengthen their own survival and capabilities, and jointly promote the integration and development of innovation resources. The accretion and re-creation of value ultimately drives the operation, evolution and development of the emerging technological innovation ecosystem [23]. From the perspective of value co-creation, the symbiotic environment of the emerging technology innovation ecosystem includes the policy environment, economic environment, and social and cultural environment. A good symbiotic environment can correctly guide the development direction of emerging technologies through reasonable internal and external governance and supervision mechanisms, and avoid innovation entities. Opportunism and unfair competition among individuals, accelerating the application of emerging technologies, coordinating the overall development of the emerging technology innovation ecosystem, and ultimately realizing value co-creation. The theory of symbiotic evolution holds that the cooperative relationship formed between different species through the flow and integration of innovative resources is the key to maintaining the balance of the ecosystem [24] and realizing the evolution from independent development to mutually beneficial symbiosis [25]. Emerging technological innovation ecosystems imply the conceptual framework of ecology, and the symbiotic model of its innovation subjects is similar to the evolution of biological populations [26], including independent coexistence, competition, parasitism, symbiosis, mutual benefit. Symbiotic 5 modes. Independent coexistence means that innovation subjects do not affect each other and develop independently; competition mode refers to resource competition and competition among different innovation subjects for their own development needs in an environment with limited innovation resources; parasitic mode refers to innovation. The development of one subject suffers while the other develops a symbiotic relationship that benefits; the partial-benefit symbiosis model refers to the symbiotic relationship in which one party develops and benefits while the other develops unaffected during the interaction process of innovation subjects; The high-level interactive relationship

formed by the main body through mutual cooperation and sharing of resources can promote mutual cooperation and win-win while achieving their own scale growth.

### 3.2. Emerging technology innovation ecosystem symbiotic evolution model based on Logistic model

#### 3.2.1. Research Hypothesis

Hypothesis 1: The emerging technology innovation ecosystem is composed of core innovation layer, auxiliary innovation layer, and application innovation layer three types of innovation subjects. Restricted by certain environmental factors, the process of innovation subjects from development to extinction is restricted and affected by various factors.

Hypothesis 2: Under the constraints of the resource environment, the maximum scale of the innovation subject is  $Q^*$ , when the scale reaches the maximum, the scale of the innovation subject will no longer increase.

Hypothesis 3: The growth of the three types of innovative subjects when their qualitative parameters are independent conforms to the growth of the Logistic model. During the evolution process, the growth rate of a certain type of innovative subjects will be affected by the scale and density of other types of innovative subjects. Due to the total amount of system resources The increase in the density of a certain type of innovation subject scale will lead to intensified competition for innovation resources, thereby reducing the growth rate of other types of innovation subjects.

Hypothesis 4: The model is in a stable state when the marginal cost of the growth scale of the innovation subject is equal to the marginal benefit, and the scale of the innovation subject is in the best state and does not grow any longer.

Hypothesis 5: The symbiotic development process of the three types of innovation subjects is a process of mutual restriction and mutual promotion. When the symbiosis coefficient is positive, each innovation subject benefits, and when the symbiosis coefficient is negative, the development of each innovation subject is blocked.

#### 3.2.2. Model Construction

The evolution process of the emerging technology innovation ecosystem from birth to growth is essentially a process in which the scale of different innovation subjects in the system continues to increase, innovation capabilities continue to improve, and all parties collaborate to create value. Like the natural biome, it has environmental adaptability. characteristics similar to those of biological communities, such as sexuality, competition, and collaboration, the study of

its internal subject scale, structure, and overall evolution law requires reference to ecological evolution methods. Under certain resource and environment conditions, each innovation subject in an emerging technological innovation ecosystem. The scale of development and the evolution model interact and influence each other, and there is a complex dynamic coupling relationship among the various subjects, and a multilateral cooperation and coordination mechanism is gradually formed. Therefore, firstly, with the help of the ecological Logistic model, the growth law of the scale of different participants in the ecosystem is explored, and the symbiotic evolution model of the emerging technology innovation ecosystem is constructed. Assuming that  $Q_i(t)(i=1,2,3)$  are the scales of the core innovation layer, auxiliary innovation layer, and application innovation layer respectively,  $r_i(i=1,2,3)$  are the natural growth rates of the three types of symbiotic units,  $Q_i^*(i=1,2,3)$  are the maximum population size of this type of symbiotic subject. Since the symbiotic relationship between the three types of innovation subjects is different in strength, the symbiotic dynamic evolution model among the three is obtained through the extended Logistic model as follows:

$$\begin{cases} \frac{dQ_1}{dt} = r_1 Q_1 \left( 1 - \frac{Q_1}{Q_1^*} + \lambda_{12} \frac{Q_2}{Q_2^*} + \lambda_{13} \frac{Q_3}{Q_3^*} \right) & Q_{1(0)} = Q_{10} \\ \frac{dQ_2}{dt} = r_2 Q_2 \left( 1 - \frac{Q_2}{Q_2^*} + \lambda_{21} \frac{Q_1}{Q_1^*} + \lambda_{23} \frac{Q_3}{Q_3^*} \right) & Q_{2(0)} = Q_{20} \\ \frac{dQ_3}{dt} = r_3 Q_3 \left( 1 - \frac{Q_3}{Q_3^*} + \lambda_{31} \frac{Q_1}{Q_1^*} + \lambda_{32} \frac{Q_2}{Q_2^*} \right) & Q_{3(0)} = Q_{30} \end{cases} \quad (1)$$

Among them, in formula (1),  $Q_{i(0)}(i=1,2,3)$  represents the core innovation layer, auxiliary innovation layer, and application innovation layer in the emerging technology innovation ecosystem. The initial population size,  $r_i Q_i(i=1,2,3)$  respectively reflects the development trend of the core innovation layer, auxiliary innovation layer, and application innovation layer;  $1 - Q_i / Q_i^*(i=1,2,3)$  is the Logistic coefficient, which indicates the proportion of the remaining resources in the system to the total resources, that is, the three types of innovation subjects in the core innovation layer, auxiliary innovation layer, and application innovation layer due to the total amount of innovation resources Restrictions lead to stunted development.  $\lambda_{ij}(i \neq j; i = 1, 2, 3; j = 1, 2, 3)$  represents the symbiotic interaction coefficient between symbiotic subjects, which means that symbiotic subject  $j$  has a relationship with symbiotic subject  $i$  in the population The degree of influence in terms of size.

**Table 1.** Symbiotic evolution models of emerging technology innovation ecosystems

Ranges	Symbiosis	features
$\lambda_{12}, \lambda_{13}, \lambda_{21}, \lambda_{23}, \lambda_{31}, \lambda_{32} = 0$	independent coexistence	The three types of innovation subjects do not affect each other and develop independently
$\lambda_{12}, \lambda_{13}, \lambda_{21}, \lambda_{23}, \lambda_{31}, \lambda_{32} < 0$	Competitive symbiosis	Three types of innovative subjects compete for similar resources. When the symbiosis coefficients are equal, there is an equal competition mode; when the symbiosis coefficients are not equal, there is a vicious competition mode
$\lambda_{12}\lambda_{21} < 0, \lambda_{13}\lambda_{31} < 0, \lambda_{23}\lambda_{32} < 0$	Symbiosis	The three types of innovation subjects have a parasitic symbiotic relationship, the innovation subjects with a positive symbiosis coefficient benefit, and the innovation subjects with a negative symbiosis coefficient suffer
$\lambda_{12} = 0, \lambda_{21} > 0$ or $\lambda_{12} > 0, \lambda_{21} = 0;$ $\lambda_{13} = 0, \lambda_{31} > 0$ or $\lambda_{13} > 0, \lambda_{31} = 0;$ $\lambda_{23} = 0, \lambda_{32} > 0$ or $\lambda_{23} > 0, \lambda_{32} = 0;$	Symbiosis	The three types of innovation subjects have a symbiotic relationship of partial benefit, the innovation subjects with a positive symbiosis coefficient benefit, and the innovation subjects with a zero symbiosis coefficient have no influence on other types of innovation subjects
$\lambda_{12}, \lambda_{13}, \lambda_{21}, \lambda_{23}, \lambda_{31}, \lambda_{32} > 0$	Mutualism	There is a mutually beneficial symbiotic relationship among the three types of innovation subjects, and the symbiosis coefficient is positive

### 3.2.3. Model Analysis

According to the combination and analysis of the values of the symbiosis coefficient, the symbiotic evolution model of the emerging technology innovation ecosystem as shown in Table 1 can be obtained.

The symbiotic evolution of innovation subjects in the emerging technology innovation ecosystem is a dynamic game process. According to Table 1, different combinations of symbiosis coefficients determine different symbiosis modes, and the size of the symbiosis coefficient determines whether the equilibrium point of the ecosystem is in an equilibrium state. Different symbiotic relationships cause the dynamic system to evolve in different directions, and finally reach an equilibrium state. The symbiotic evolution result of the emerging technology innovation ecosystem is determined by the value of the symbiotic effect coefficient. In order to explore the symbiotic evolution results among the three types of innovation subjects, the stability analysis of the equilibrium point of equation (1) can be carried out. Let  $\frac{dQ_1}{dt} = \frac{dQ_2}{dt} = \frac{dQ_3}{dt} = 0$  get 8 local equilibrium points of symbiotic evolution of core innovation layer, auxiliary innovation layer

and application innovation layer. At this time, 8 equilibrium points constitute the symbiotic evolution ecosystem of innovation subject Boundary, the Jacobian matrix is used, and the model stability is analyzed using Lyapunov's first method. An equilibrium point is stable if all eigenvalues of matrix J are negative, and unstable if at least one of the eigenvalues of matrix J is positive. The Jacobian matrix formula is as follows:

$$J = \begin{bmatrix} \frac{\partial F(Q_1)}{\partial Q_1} & \frac{\partial F(Q_1)}{\partial Q_2} & \frac{\partial F(Q_1)}{\partial Q_3} \\ \frac{\partial F(Q_2)}{\partial Q_1} & \frac{\partial F(Q_2)}{\partial Q_2} & \frac{\partial F(Q_2)}{\partial Q_3} \\ \frac{\partial F(Q_3)}{\partial Q_1} & \frac{\partial F(Q_3)}{\partial Q_2} & \frac{\partial F(Q_3)}{\partial Q_3} \end{bmatrix}, \text{ where } \frac{\partial F(Q_1)}{\partial Q_1} = r_1 \left(1 - 2 \frac{Q_1}{Q_1^*} + \lambda_{13} \frac{Q_3}{Q_3^*} + \lambda_{12} \frac{Q_2}{Q_2^*}\right), \frac{\partial F(Q_1)}{\partial Q_3} = \frac{r_1 Q_1 \lambda_{13}}{Q_3^*}, \frac{\partial F(Q_2)}{\partial Q_3} = \frac{r_2 Q_2 \lambda_{23}}{Q_3^*}, \frac{\partial F(Q_3)}{\partial Q_1} = \frac{r_3 Q_3 \lambda_{31}}{Q_1^*}, \frac{\partial F(Q_3)}{\partial Q_2} = \frac{r_3 Q_3 \lambda_{32}}{Q_2^*}, \frac{\partial F(Q_3)}{\partial Q_3} = r_3 \left(1 - 2 \frac{Q_3}{Q_3^*} + \lambda_{31} \frac{Q_1}{Q_1^*} + \lambda_{32} \frac{Q_2}{Q_2^*}\right),$$

that is, when the coefficient equilibrium point makes the Jacobian When the determinant  $\text{Det}(J) > 0$  of the matrix J and the trace  $\text{Tr}(J) < 0$ , the equilibrium point is a stable equilibrium point. The equilibrium point and stability analysis of the dynamic evolution of the ecosystem coefficient are shown in Table 2:

**Table 2.** Stability conditions

equilibrium point	Eigenvalues	stability condition
$E_1(0,0,0)$	positive	unstable
$E_2(Q_1^*, 0, 0)$	negative	$\lambda_{21} < -1, \lambda_{31} < -1$
$E_3(0, Q_2^*, 0)$	negative	$\lambda_{12} < -1, \lambda_{32} < -1$
$E_4(0, 0, Q_3^*)$	negative	$\lambda_{13} < -1, \lambda_{23} < -1$
$E_5 \left(0, \frac{(1+\lambda_{23})Q_2^*}{1-\lambda_{23}\lambda_{32}}, \frac{(1+\lambda_{23})Q_3^*}{1-\lambda_{23}\lambda_{32}}\right)$	positive value	$\lambda_{32}\lambda_{23} < 1, \lambda_{13} < -1, \lambda_{12} < -1$
$E_6 \left(\frac{(1+\lambda_{13})Q_1^*}{1-\lambda_{13}\lambda_{31}}, 0, \frac{(1+\lambda_{31})Q_3^*}{1-\lambda_{13}\lambda_{31}}\right)$	positive value	$\lambda_{32}\lambda_{23} < -1, \lambda_{23} < -1, \lambda_{21} < -1$ $\lambda_{12}\lambda_{21} < -1, \lambda_{31} < -1, \lambda_{32} < -1$ $\lambda_{12}\lambda_{21} > 1$
$E_7 \left(\frac{(1+\lambda_{12})Q_1^*}{1-\lambda_{12}\lambda_{21}}, \frac{(1+\lambda_{21})Q_2^*}{1-\lambda_{12}\lambda_{21}}, 0\right)$	positive value	$Q_3^*(\lambda_{12} + 1) + \lambda_{12}\lambda_{23} + \lambda_{13} > 0$ $Q_3^*(\lambda_{21} + 1) + \lambda_{21}\lambda_{13} + \lambda_{23} > 0$
$E_8(p, q, k)$	negative	$\lambda_{31}[1 - \lambda_{31}(\lambda_{13} + \lambda_{12}\lambda_{23}) - \lambda_{21}(\lambda_{12} + \lambda_{32}\lambda_{13}) - \lambda_{32}\lambda_{23}] > 0$

Note: In equilibrium point  $E_8$ ,  $p = \frac{-Q_1^*(\lambda_{12} + \lambda_{13} + \lambda_{12}\lambda_{23} + \lambda_{13}\lambda_{32} - \lambda_{23}\lambda_{32} + 1)}{\lambda_{12}\lambda_{21} + \lambda_{13}\lambda_{31} + \lambda_{23}\lambda_{32} + \lambda_{12}\lambda_{23}\lambda_{31} + \lambda_{13}\lambda_{21}\lambda_{32} - 1}$ ,  $q = \frac{-Q_2^*(\lambda_{21} + \lambda_{23} + \lambda_{13}\lambda_{21} + \lambda_{23}\lambda_{31} - \lambda_{13}\lambda_{31} + 1)}{\lambda_{12}\lambda_{21} + \lambda_{13}\lambda_{31} + \lambda_{23}\lambda_{32} + \lambda_{12}\lambda_{23}\lambda_{31} + \lambda_{13}\lambda_{21}\lambda_{32} - 1}$ ,  $k = \frac{-Q_3^*(\lambda_{31} + \lambda_{32} + \lambda_{12}\lambda_{31} + \lambda_{21}\lambda_{32} - \lambda_{12}\lambda_{21} + 1)}{\lambda_{12}\lambda_{21} + \lambda_{13}\lambda_{31} + \lambda_{23}\lambda_{32}}$ .

## 4. Main Conclusions and Policy Recommendations

### 4.1. Main conclusions

This study takes the emerging technology innovation ecosystem as the research object, and builds a symbiotic evolution model of the emerging technology innovation ecosystem from the perspective of value co-creation. Through the analysis and simulation of the stability and equilibrium state of the model, it is discussed from two dimensions: theory and demonstration. The evolution process of the emerging technology innovation ecosystem. The main conclusions are as follows:

(1) The emerging technology innovation ecosystem is a complex system in which four types of innovation subjects, namely the core innovation layer, auxiliary innovation layer, supporting innovation layer, and application innovation layer, create value collaboratively in a certain symbiotic environment around value acquisition and innovation

interaction. Among them, the core innovation layer masters the core technology and innovation driving force, and is the starting point of value co-creation and the node of the value network; the auxiliary innovation layer deploys the full-scenario application of emerging technologies, and is the carrier to realize value transfer; the support innovation layer provides technology, The support of funds and talents cooperates with the core innovation layer and auxiliary innovation layer to complete the improvement and upgrading of value co-creation; the application innovation layer is the ultimate flow of innovation value, and consumers in the emerging technology innovation ecosystem are no longer just serving Recipients and users of product value, personal resources owned by end consumers, such as technology, knowledge stock and demand information can realize value co-creation with other stakeholders, and the innovation layer synergy drives the operation and evolution of emerging technology innovation ecosystems And development.

(2) The size of the symbiotic coefficient among innovation subjects determines the equilibrium state of the symbiotic

evolution of the emerging technological innovation ecosystem. The symbiotic evolution of the emerging technology innovation ecosystem is a process of synergistic coupling and interaction among innovation subjects. The scale growth of each type of innovation subject is closely related to the number and growth rate of other subjects in the symbiosis system. When the symbiosis coefficients are all positive, each type of innovation subject will benefit from mutual synergy, and the growth ceiling of its own development will rise. The greater the symbiosis coefficient, the greater the increase in the growth ceiling.

(3) The symbiotic relationship between innovation subjects in the emerging technology innovation ecosystem shows a transformation from independent coexistence, competition, parasitism, and partial symbiosis to mutually beneficial symbiosis. Under the influence of different symbiosis coefficients, the maximum scale and growth rate of each innovation subject are constantly changing. Under the mutual-benefit symbiosis mode, the development state of the emerging technological innovation ecosystem reaches the best, and the symbiosis coefficients among the three types of innovation subjects are all positive. The three types of innovation subjects benefit from cooperation with each other, and the final stable state of the innovation subjects is greater than the maximum scale when they develop independently. Therefore, the innovation subjects in the system should strive to develop and evolve towards a mutual-benefit symbiosis model.

## 4.2. Policy recommendations

The sound operation of emerging industries requires not only the R&D and application of emerging technologies, but also the support of a sound and coordinated innovation ecosystem, and the instability of emerging technologies requires that the key to fostering and developing emerging industries is to promote innovation Resource integration and industrial integration development. Based on the above conclusions, the following suggestions are put forward for the development of the emerging technology innovation ecosystem:

(1) Fully balance the dynamics of symbiotic evolution of emerging technological innovation ecosystem populations. The innovation subject in the ecosystem should improve the fit of the development strategy centered on innovation, and promote the modular division of labor and the overall optimization of innovation elements within the industry. At the same time, guided by market demand, strengthen the application of emerging technologies, create a full range of emerging technology application scenarios, and jointly coordinate the relationship between the two major factors of interest-driven and synergistic symbiosis in the emerging technology innovation ecosystem.

(2) Optimize the symbiotic environment of the emerging technology innovation ecosystem. The government should formulate relevant preferential policies and regulation strategies to stimulate innovation, optimize the symbiotic environment of the system, and make it easier for more innovation subjects to join the emerging technology innovation ecosystem. It should also strengthen the standardization and institutionalization of system cooperation and innovation, and provide support for the development of system members. A transparent and unobstructed information environment can enhance the mutual relationship, reduce the probability of opportunistic behavior among innovative

subjects, reduce the risk cost of innovation, and promote the stable development of the symbiotic system.

(3) Formulate and improve an efficient collaborative innovation mechanism for emerging technology innovation ecosystems. Enterprises should strengthen the interaction and cooperation with users and the market, deploy emerging technologies in scenarios, further expand the breadth and depth of the value of emerging industries, and gradually form a technology chain network composed of horizontal business chains and vertical industry flows. Realize the symbiotic evolution of the emerging technology innovation ecosystem from low-level to high-level evolution.

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