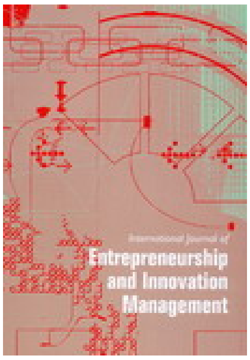

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The symbiosis evolution mechanism and simulation research of developed science-based innovation ecosystem

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Abstract: Based on the perspective of the developed science-based innovation ecosystem, this research constructs a biomedical innovation ecosystem structure model that integrates the Lotka-Volterra model to conduct empirical research on the symbiotic evolution of innovation populations in the system and discusses the cooperative evolution law among innovation populations in the system, with taking China's biomedical industry as an example. The research results indicate that in the biomedical industry based on developed-science innovation ecosystem, the development of the industry strongly depends on scientific research, and the innovation vitality is mainly concentrated at the university, scientific research institutes, and enterprises with R&D capabilities. This research provides a theoretical and practical significance for the breakthrough in national innovation from the perspective of the developed science-based innovation ecosystem.

Keywords: innovation ecosystem; innovation based on developed science; innovation population; biomedical industry; logistic model; evolutionary simulation.

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1 Introduction

The relationship between science and innovation is changing greatly. Science-based innovation has been affecting the whole world in an unprecedented way, which completely disrupts the concept of technology-based innovation in the past half century (Zhang and Lei, 2018). With the boundary between developing science and developed science emerging gradually, innovation based on developed science is the continuous diffusion of scientific knowledge-based research achievements into the industry, which promotes interaction between the innovative developed-industry and related scientific fields with immature industrial science; and the part of knowledge-innovation is concentrated in the upstream of the innovation chain – R&D department (Cardinal et al., 2001). The innovation based on developing science is an interactive mode of industrial science in which the industry is not yet mature and the corresponding scientific field is mature but has not achieved major scientific research breakthroughs (Thursby and Thursby, 2002; Malerba, 2004; Chen et al., 2013). If there is no science-based innovation, an average of 9% of new processes and 11% of new products will not appear (Mansfield, 1991). From the early semiconductor industry to emerging industries in recent years such as biopharmaceuticals, nanotechnology, chemistry, information, new energy, new materials, etc., they are all established and developed on scientific innovation which is on the front-end foundation of technology. The formation and development of those industries have triggered a new industrial revolution, and even promoted the transformation of social and economic paradigm.

From the ternary flow theory to the aero-engine industry, from modern chemistry to molecular science, from computer molecular editing to the application of human synthetic materials, the establishment of an innovation ecosystem based on developed science has been the only way to make breakthroughs and improve independent innovation capabilities in the whole country. Based on the purpose of jointly enhancing capabilities, supporting new products, satisfying customer needs, and absorbing new innovative ideas, the innovation ecosystem is a kind of business ecosystem which is formed by the establishment of competition and cooperation between core enterprises and other enterprises (Rohrbeck et al., 2009). The innovation ecosystem based on developed science is an organic whole of collaborative innovation of innovative populations that influence each other, and plays a more important role in the process of innovation and development in the era of knowledge economy. Compared with the innovation ecosystem based on developing science, the innovation ecosystem based on developed science emphasises that innovation is the accumulation and integration of knowledge in multidisciplinary development. The developed science-based innovation mainly comes from universities/scientific research institutes, which needs large R&D investment, makes strong breakthrough and contains abundant and continuous technological opportunities (Zhang and Lei, 2018).

Biopharmaceutical industry is an important part of China's national economy, and plays a vital and active role in protecting the health of Chinese people and promoting the stable development of China's economy. It is also a measure of a country's independent innovation level and an important gauge of overall economic strength. However, the development of biopharmaceutical industry relies on science-based innovation. The outbreak of the new crown pneumonia in early 2020 has challenged China's medical and health system, which has also prompted us to reflect on China's existing innovation system: recently nearly half of China's core patented technologies are concentrated in industries with developing scientific innovation, such as wireless transmission, manufacturing, etc. Nevertheless, the core patents based on developed scientific innovations such as biomedicine and chemical industry are still inferior to developed countries. Some key components, parts and raw materials of those industries are dependent on imports, and their innovative capabilities based on developed science are weakened to the danger edge. From a theoretical point of view, innovation based on developed science is an extremely important aspect and critical part in the development of scientific and technological innovation, and an innovation ecosystem based on developed science is an effective organisational form for collaborative innovation of innovative entities. Therefore, this article selects the biopharmaceutical industry to analyse the evolution mechanism of the developed science-based innovation ecosystem, and takes Zhongguancun and Zhangjiang Life Science Park as examples to explore the evolution mechanism of the innovation population in the developed science-based innovation ecosystem. The development of the pharmaceutical industry has valuable reference significance and promotes the further development of frontier fields based on developed science.

2 Theoretical framework

2.1 Science-based innovation

Since the 21st century, innovation activities have increasingly relied on scientific research, and the relationship between science and innovation is changing almost unnoticed. Science-based innovation refers to innovation activities in which scientific research directly promotes technological development, and the technological invention process strongly relies on new scientific discoveries (Stokes, 1999). The knowledge of this kind of innovation mainly comes from universities, scientific research institutions and research-intensive enterprises (Lin and Lei, 2014), that is, its innovation sources mostly come outside the enterprise, and the essence of product innovation is to promote industrial development through scientific research (Zhang and Lei, 2015). Science-based innovation achievements are often protected by patents, and the innovation process is difficult to be replicated (Cardinal et al., 2000). The R&D investment of this innovation is often high, and the research and development cycle of new innovation achievement are longer (Cardinal et al., 2000; Styhre, 2008), and the time from the scientific innovation achievement to the real commercial products is 17.61 years on average (Zhang et al., 2015), and it is accompanied by high risks (Pisano, 2010); biomedicine, organic chemistry, cosmetics and other industries are typical science-based innovation industries (Zhang and Lei, 2015), and an average age of commercialising biomedical scientific fruits is 21.08 years (Zhang et al., 2015).

According to the different development stages of scientific knowledge, science-based innovations can be divided into developed scientific models and developing scientific models (Cardinal et al., 2001). In the innovation model based on developed science, basic scientific knowledge has been sorted out in the R&D stage, and the innovation process is almost one-way (David, 1992). The innovation of knowledge is concentrated in the upstream – R&D department. Once it is patented, innovation continues from the upstream R&D activities to downstream sales activities through the production process of the industrial chain. Downstream activities depend on the innovative knowledge (including explicit and tacit knowledge) of the R&D department to create value. In the innovation model based on developing science, innovation activities are generally not a one-way flow, but innovation entities learn while doing, and the innovation entities are closely linked and interact with production and sales activities. This is because the knowledge of this innovation is relatively weak and its experience is limited. Under the role of an integrated team, the cooperation and interaction of R&D, production, marketing and other activities are essential for the development of new products (Cardinal et al., 2001; Barnett and Clark, 1998; Pisano, 1994; Senker and Faulkner, 1992). The research shows that pre-learning refers to small-scale experiments in the laboratory, without the need for expensive iterations between R&D and production, which is more common in innovative models based on developed science (Pisano, 1994). Before the production process, R&D personnel will produce small batches/pilot products out of developed science-based innovation. Once the final product is confirmed in the R&D process, the R&D personnel will determine the final ‘precision formula’ for the subsequent production process. In the field of developed science, the ‘producers’ in the system can use the models and successes obtained from innovative tests to make a greater degree of prediction on the basis of small batch production (Pisano, 1994). And the pre-learning almost occurs in the research and development stage of a science-based innovation. Due to the nature of the industry based on developed science, the uncertainty in the innovation process mainly comes from ‘upstream’ activities, and the reason of the uncertainty occurring is mainly because’producers’need to re-develope new product out of scientific knowledge identified by them.

2.2 Innovation ecosystem

In 2004, the concept of ‘innovation ecosystem’ was formally proposed by the US Presidential Advisory Committee on Science and Technology (PCAST, 2004) for the first time, and then scholars pointed out that the innovation ecosystem is composed of related enterprises that are in different ecological niches (Iansiti and Levien, 2004). The innovation ecosystem is based on the innovation ecology. It is to promote innovation to connect with innovation subjects. The root of innovation development lies in the efficiency of information flow between innovation subjects in this connection network (Metcalfe and Ramlogan, 2008). The innovation ecosystem simulates the economic dynamics of the complex relationship between innovation subjects. The fundamental purpose of this complex relationship is to achieve innovation and development (Jackson, 2012). Furthermore, the innovation ecosystem is a network of relationships between organisations formed in order to complete technological innovation and commercialisation of research fruits. In this network, both technological innovation and commercial transformation of research fruits have an irreplaceable position (Zheng, 2010; Yang, 2014). As a general complex system, it is hierarchical, dissipative, and dynamic (Huang, 2003), which emphasises ecological characteristics, such as subject heterogeneity, symbiotic evolution (Moore, 1993), and self-organisation (Adner, 2006). In summary, this article believes that the innovation ecosystem based on developed science is a value relationship network formed by the competition and cooperation relationship between the innovation subject and other participating subjects in the development of a regional innovation, which depends on the formation of developed science to jointly improve capabilities, support new products, meet customer needs and absorb new innovative ideas.

At present, domestic and foreign scholars have conducted in-depth research on the innovation ecosystem through qualitative and quantitative methods from the perspective of ecology. The innovation ecosystem mainly focuses on the four aspects of innovation subject, innovation environment, product development, and innovation resources, emphasising the integration of internal and external innovation resources in the whole process of innovation from scientific research, technology transfer, product development to product marketisation (Trott and Hartmann, 2009; West and Bogers, 2013). As a metaphor of a complicated ecological system, the innovation ecosystem follows self-organising evolution, and its evolution mechanism is similar to the laws of heredity, variation, derivation, and selection of natural ecosystems (Luo and Lin, 2015). It has mainly experienced germination, growth, reproduction, Four stages of differentiation (Tang et al., 2019). The innovation environment is vital to the dynamic evolution of the innovation ecosystem (Kaplan, 2012). The key to maintaining the evolution of the system is to handle the correct innovation-related issues at the right time (Hwang and Horowitt, 2012). The power of the system mainly comes from the government, enterprises and other stakeholders (Yanru, 2009).

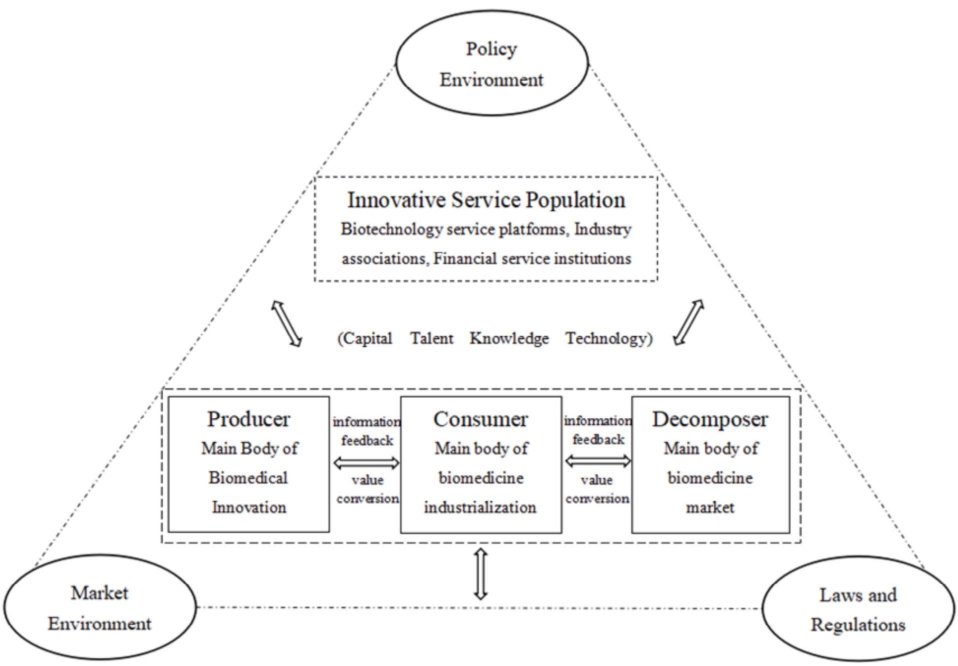
On the basis of the summary and conclusion of existing researches, this paper intends to apply the ecological theory and self-organisation theory to analyse a biomedical innovation ecosystem with taking China's biomedical industry as an example, and construct a developed science-based innovation ecosystem structure model with logistic equation from the perspective of the developed science-based innovation. And this research integrates the Lotka-Volterra model to conduct empirical research on the symbiotic evolution of innovation populations in the system of Zhongguancun and Zhangjiang Life Science Park, and discusses the cooperative evolution law among innovation populations in the system through the software of origin. At last, according to the conclusion of the above research some suggestions for the biomedical innovation ecosystem would be raised to promote the innovation based on 'developed' science.

3 Research method

3.1 Structural model of biomedicine innovation ecosystem

Based on the existing research, this article builds an innovation ecosystem for the biomedical industry Structure model from the perspective of ecology, which compares the innovation ecosystem to the natural ecosystem, divides the main participants in the system (universities, research institutes, enterprises, governments, consumers, etc.) into biological factors and non-biological factors. With comparing the biological chain analogy to the innovation chain, the biological factors in the innovation system mainly include producers (the main body of biomedicine innovation), consumers (the main body of biomedicine industrialisation), and decomposers (the main body of biomedicine marketisation); non-biological factors are the external environment (innovation environment) mainly includes policy environment, laws and regulations, market environment, etc., as well as some other special components-innovation service institutions (biotechnology service platforms, related industry associations, financial service institutions, etc.). The structure model is shown in Figure 1.

Figure 1 Structural model of biomedicine innovation ecosystem



In an innovation ecosystem based on developed science, industrial development strongly relies on scientific research, and innovation activities within the system are mainly concentrated in the upstream of the innovation chain – the main part of innovation (i.e., producers). Therefore, the innovation subject mainly refers to the group with strong scientific research ability, including the group of producers with innovative ability such as enterprises, universities/scientific research institutes, etc. They are the behaviour subject and original innovation of the entire system, which make good use of innovation resources and drive the evolution of the system; the subject of biomedicine industrialisation plays the role of a consumer in the system. By commercialising the scientific research results of the innovative subject, scientific innovation promotes the development of technology and realises the transformation of scientific innovation capabilities into production. What's more, through the information feedback mechanism the occurrence of scientific innovation would be further promoted; the subject of innovation marketisation mainly includes biomedical sales companies, hospitals and patients. It is the decomposer population of the system, which plays a role in guiding the innovation of the innovative subject through the information feedback in the system; the innovation environment mainly includes the market environment, policy environment, laws and regulations. The government leads to build various platforms to support and supervise the innovative behaviour of innovation entities (enterprises, universities/scientific research institutes), which can integrate the elements of innovative resources by formulating biomedical innovation policies and industry standards. In addition, the innovative service organisation is the service group in the system, mainly including biotechnology service platforms, related industry associations, financial service institutions, etc., which support the innovative behaviour of innovation subjects in the system.

3.2 Dynamic evolution model of innovation ecosystem

The research on the evolution mechanism of the innovation ecosystem should be conducted based on the stages of the innovation process (Rohrbeck et al., 2009), and the research on its evolution mechanism usually adopts methods such as case studies and computer simulation. Case studies require dynamic large sample data for empirical purposes, and computer simulation can systematically simulate the evolution of the system in the absence of large samples. It is an effective method to study complex systems. When it is difficult to solve with a model, the method of computer simulation will achieve a multiplier effect. The development of the innovation ecosystem is similar to that of the natural ecosystem. Its self-organising evolution grows in a limited resource environment and cannot develop indefinitely. The development of the system follows the Logistic mechanism, that is, its development trend is the combined effect of positive feedback force and negative feedback force. Therefore, this paper studies its evolution mechanism by constructing the logistic evolution equation.

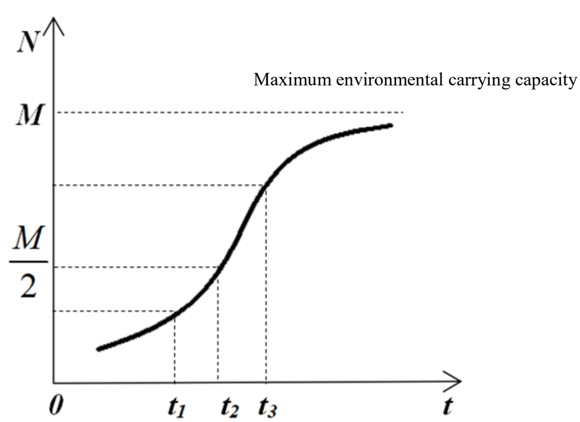
3.2.1 Dynamic evolution model of biomedicine innovation ecosystem

The innovation process of the biomedical industry strongly relies on new scientific discoveries (the 'upstream' of the innovation chain), and producers and users (the 'downstream' of the innovation chain) cannot improve it. This linear process mainly includes drug discovery and pre-clinical Research and development, clinical research, small test, pilot test and industrialisation, etc. (Liu, 2016). Knowledge innovation is mainly concentrated in universities, research institutes, research and development enterprises and other innovation entities. Innovative knowledge mainly flows from upstream (knowledge research and development) to downstream (clinical applications), which is an innovative model based on developed science. Therefore, the biomedicine industry has distinctive features such as a strong dependence on scientific research and prior learning. Meanwhile, the biomedical industry with special properties of safety and ethics provides service for human life and health. In the development of this industry, we must consider the safety of some special biotechnologies (such as human stem cell research, cloning technology, genetically modified technology) and their impact on morals and ethics. Because the innovation process of this industry is long and complex and relies on basic scientific research, it also has the characteristics of long cycle, high investment, high technology, high risk, and high return. The study of the biomedical innovation ecosystem is to analyse the innovation ecosystem based on developed science from the perspective of specific industries, clarify the evolutionary power of the system, and explore its evolutionary laws, which will improve the independent innovation capability of China's biomedical industry. Therefore, this paper introduces the logistic curve equation to analyse the evolution process of the biomedical innovation ecosystem, and the evolution process can be described by the following mathematical equation:

$$\frac{dN(t)}{dt} = \mu N(t)\left(1 - \frac{N(t)}{M}\right)$$

Among them, $N(t)$ represents the comprehensive index for the development of the biomedical innovation ecosystem at time t. This article selects the innovation resources occupied by the innovation subjects in the system for analysis, and the development of the system is realised by increasing the innovation resources occupied by the innovation subjects. The increase of innovation resources occupied depends on the interaction between the system and the environment; $dN(t) / dt$ represents the growth rate of the resource occupation of the innovation subject in the system at any time; $\mu(\mu > 0)$ represents the internal growth rate of the biomedical innovation ecosystem, which is mainly related to the internal member structure of the system, the resource utilisation rate and the innovation ability of the main body; M ($M > 0$) represents the maximum carrying capacity of the environment of the biomedical innovation ecosystem, which is mainly related to factors like the innovation policy, economic development and technical conditions, etc.

Figure 2 Evolution curve of biomedical innovation ecosystem



$N(t)$ is a dynamic factor in the equation, which increases with the development of time t and symbolises the positive feedback mechanism of system evolution. $N(t) / M$ is the amount of total resources consumed at time t, and the remaining resources

$(1 - N(t) / M)$ are the inhibitory factors, which decrease with the increase of time t and represents the negative feedback mechanism of system evolution. Analysis of its coefficients can be obtained:

1 When the innovation resource occupation $N(t)$ of the innovation subject in the system approaches 0, the remaining resources $(1 - N(t) / M)$ approaches 1, indicating that the innovation resources occupied by the innovation agent in the system have not yet been developed and utilised, then the evolution trend of the biomedical innovation ecosystem is exponential growth.

2 When the innovation resource occupation $N(t)$ of the innovation subject in the system approaches M, the remaining resources $(1 - N(t) / M)$ approach 0, indicating that the innovation resources occupied by the innovation subject in the system have been fully utilised. At this time, the evolutionary trend of the biomedical innovation ecosystem is saturated.

3 When the innovation resource occupation of the innovation subject within the system gradually increases from 0 to M, the remaining resources $(1 - N(t) / M)$ progress from 1 to 0, it indicates that the 'growth space' for system evolution is gradually shrinking, and the potential The maximum rate of increase gradually decreased.

3.2.2 Population symbiosis evolution model of biomedicine innovation ecosystem

Assuming that there are two innovation groups A and B in the biomedical innovation ecosystem dominated by the Science Park, the amount of their innovation resources are denoted as $n_1(t)$ and $n_2(t)$, respectively. μ_1 and μ_2 are their inherent growth rates, respectively. M_1 and M_2 are respectively the maximum capacity of the environment for its individual growth. When the innovation population evolves independently in the system environment, the change in the amount of innovation resources possessed by the innovation population conforms to the logistic evolution mechanism, and the innovation population has

$$\frac{dn_1(t)}{dt} = \mu_1 n_1(t)\left(1 - \frac{n_1(t)}{M_1}\right) \tag{1}$$

From the perspective of the innovative ecosystem composed of two species and other related species, the two species are related to each other, that is, there is a relationship of $\alpha_1 = 1 / \alpha_2$ between the populations. The influence of A on B is represented by α_1, and the influence of B on A is represented by α_2. When two populations evolve in the same innovative ecological environment, population B competes with population A for the same limited resource, and the development of population B will affect the growth of population A. When measuring the evolution of the resource occupation rate of population A, the competition inhibition term of population B to A should be subtracted from the dynamic equation. The competitive effect is proportional to the innovation resource $n_2(t)$ occupied by the population B, and inversely proportional to the maximum environmental load M_2 of the population B. Therefore, under the inter-species competition, the dynamic equation of the change of population A/B's innovation resource occupation is

$$\begin{cases} \dfrac{dn_1(t)}{dt} = \mu_1 n_1(t)\left(1 - \dfrac{n_1(t)}{M_1} - \partial_1 \dfrac{n_2(t)}{M_2}\right) \\ \dfrac{dn_2(t)}{dt} = \mu_2 n_2(t)\left(1 - \dfrac{n_2(t)}{M_2} - \partial_2 \dfrac{n_1(t)}{M_1}\right) \end{cases} \tag{2}$$

By introducing competition inhibition terms, and using α_1 and α_2 to describe the relative strength of the inter-species competition symbiosis mechanism in the system, a population symbiosis evolution model is established, as shown in equation (2). The proportional coefficient α1 here represents the competition coefficient of population B to population A, and reflects the degree of inhibition of population B to the development of population A. In the same way, the proportional coefficient α_2 represents the competition coefficient of the population A to the population B, reflecting the degree of inhibition of the development of the population A to the population B.

Solving equation (2) can get two straight lines representing population capacity:

$$\begin{cases} L_1 : 1 - \dfrac{1}{M_1} n_2(t) - \partial_1 \dfrac{n_1(t)}{M_1} = 0 \\ L_2 : 1 - \dfrac{1}{M_2} n_2(t) - \partial_2 \dfrac{n_1(t)}{M_2} = 0 \end{cases}$$

This formula is an LV model of the amount of innovation resources occupied by two groups in the biomedical innovation ecosystem under the constraints of innovation resources.

It can be seen from the above definition that $\alpha_1 > \alpha_2$ means that among the resources supplying population A, population B has more resources than population A, and B has more resources than A; $\alpha_1 < \alpha_2$ means that among resources supplying population B, population If A's resource occupancy is greater than that of group B, A's resource occupancy is greater than that of B. When α_1 and α_2 are independent of each other, let:

$$\frac{dn_1(t)}{dt} = \frac{dn_2(t)}{dt} = 0$$

At this time, four equilibrium states are obtained:

$$\lambda_1(0,1);\ \lambda_2(M_1, 0);\ \lambda_3(0, M_2);\ \lambda_4\left(\frac{M_1(1-\partial_1)}{1-\partial_1\partial_2}, \frac{M_2(1-\partial_2)}{1-\partial_1\partial_2}\right)$$

By analysing its equilibrium state (as shown in Figure 3), the following conclusions can be drawn:

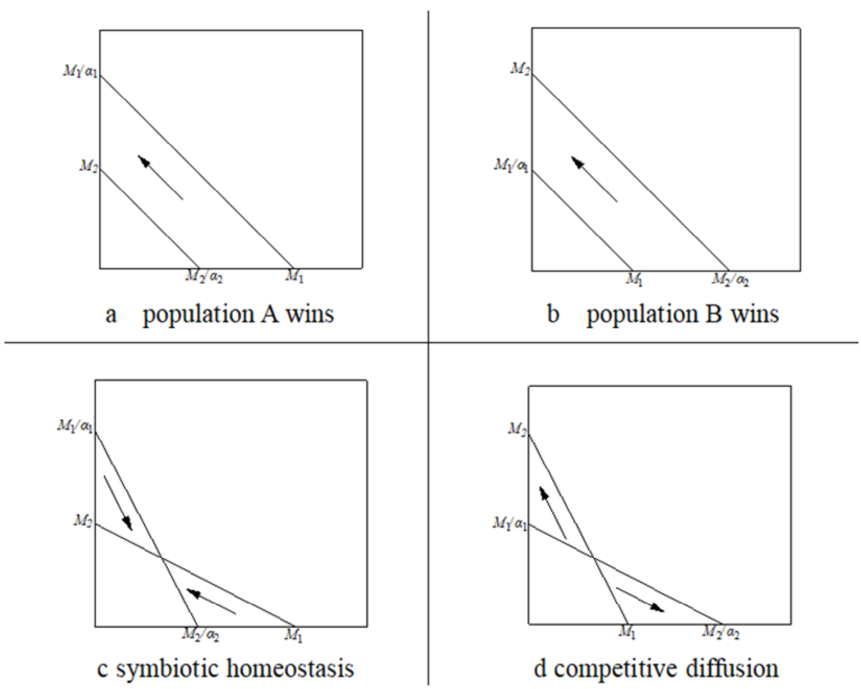
1 When $\alpha_1 < 1$, $\alpha_2 > 1$, the biomedical innovation ecosystem will evolve to a balanced state λ_2. $\alpha_1 < 1$ indicates that the resource occupancy rate of population B to population A is lower than that of population A, and $\alpha_2 > 1$ indicates that population A has a higher resource occupancy rate to population B than population B, that is, population A is more competitive than population B. As time goes by, population B will disappear, and population A's possession of innovative resources will approach the maximum carrying capacity of the environment, that is, reach the steady state λ_2 of population A, as shown in Figure 3(a).

2 When $\alpha_1 > 1$, $\alpha_2 < 1$, the biomedical innovation ecosystem will evolve to a balanced state λ_3. At this time, the evolution state in the system is exactly opposite to the steady state λ_3, as shown in Figure 3(b).

3 When $\alpha_1 < 1$, $\alpha_2 < 1$, the biomedical innovation ecosystem will evolve to a balanced state 3-c. In this state, the resource occupancy rate of population A to population B is lower than that of population B, and the resource occupancy rate of population B to population A is lower than that of population A, and both parties can achieve symbiotic steady state λ_4, as shown in Figure 3(c).

4 When $\alpha_1 > 1$, $\alpha_2 > 1$, $\alpha_1 > 1$ indicates that the resource occupancy rate of population A to population A is higher than that of population A, and $\alpha_2 > 1$ indicates that population A has a higher resource occupancy rate to population B than population B, and the system is in In an unstable state, the biomedical innovation ecosystem will be far from the equilibrium state λ_4, as shown in Figure 3(d). As time goes by, the competitiveness of a certain group will surpass that of another group, resulting in a competitive advantage, thus realising the evolution of the system to a steady state λ_2 or λ_3.

Figure 3 Symbiosis evolution mechanism of innovative populations in biomedical innovation ecosystem



4 Results

Zhongguancun Science and Technology Park and Zhangjiang Science and Technology Park are both well-known high-tech parks in China, which are representative of innovation based on developed science. Both parks focus on the development of biopharmaceuticals, high-end medical equipment, and modern medical service industries. Zhongguancun has formed a basic support platform based on the Beijing Institute of Life Sciences and Beijing Institute of Drug Control, while Zhangjiang has built a national Shanghai biomedical technology industry base. Relying on the park model of close integration of 'schools, enterprises, and regions', the two have achieved remarkable fruits in research and innovation of biomedicine. Based on the case of the biomedical innovation ecosystem led by these two science and technology parks, this article discusses its evolution mechanism.

4.1 Model parameter design

The evolution of a science-based innovation ecosystem is inseparable from scientific research, and the level of innovation capability of system science is mainly reflected in the economic output of the system (Sun et al., 2019). Therefore, this paper selects the economic output in Zhongguancun Life Science Park and Zhangjiang Life Science Park as the core variable to measure the scientific innovation of the park.

4.2 Model solving

The data of the economic output of Zhongguancun Life Science Park mainly comes from the 'Zhongguancun Science Park Yearbook', and the data of the economic output of Zhangjiang Life Science Park mainly comes from the 'Shanghai Pudong New Area Statistical Yearbook'. Based on scientific systems and operational principles, the yearbook data for 2008–2018 (statistics for 2006–2017) and the yearbook data for 2008–2019 (statistics for 2006–2018) respectively are selected. Origin is adopted to perform logistic fitting analysis on the data.

Table 1 Logistic fitting model

Logistic equation	*Adjusted R^2*
$N_1(t) = \dfrac{2789.82336}{1 + e^{636.9495940.31631t}}$	0.99376
$N_2(t) = \dfrac{444.17941}{1 + e^{430.840691-0.21382t}}$	0.95058

Perform simulation analysis on model (1). The fitted model (shown in Table 1) and the analysis of variance (shown in Table 2) are as follows.

The resource occupation of Zhongguancun Science Park in the biomedical innovation system is $N_1(t)$, and the resource occupation of Zhangjiang Science Park is $N_2(t)$. Among them, the goodness of fit (R^2) is significantly higher than 0.9, the equation fits convergence, and the variance is at the 0.05 level, indicating that the independent variable 'economic output' has a significant impact on scientific innovation in Zhongguancun Life

Science Park and Zhangjiang Life Science Park, And the fitting equation is obviously better than the actual equation.

Table 2 Variance analysis

Park name	*Project*	*DF*	*Sum of square*	*Mean square*	*F*	*Probability>F*
Zhongguancun Science and Technology Park	Regression	3	1.709E7	5.69668E6	2,240.03609	7.23421E-13
	Residual	9	22,888.08272	2,543.1203		
	Uncorrected whole	12	1.71129E7			
	Correct whole	11	4.47964E6			
Zhangjiang Science and Technology Park	Regression	3	417,152.90034	139,050.96678	426.91461	2.07903E-10
	Residual	10	3,257.11426	325.71143		
	Uncorrected whole	13	420,410.0146			
	Correct whole	12	79,095.43971			

4.3 Analysis of population evolution of biomedical innovation ecosystem

In order to facilitate the analysis of the population evolution of the biomedical innovation ecosystem, formula (3) is used to normalise the collected data to keep the data within the interval [0, 1], see Table 3.

$$H = \frac{I - I_{\min}}{I_{\max} - I_{\min}} \tag{3}$$

In formula (3), H represents the normalised processing result, I is the actual value of the normalised object, $I_{\min}$ represents the minimum value of the statistical object in each year, and Imax represents the maximum value.

Figure 4 shows the evolutionary trajectory of the two innovative populations of Zhongguancun and Zhangjiang in the biomedical innovation ecosystem since 2006. In the process of the symbiosis and evolution of these two innovative populations, the economic output value has basically maintained a continuous increase, but Zhangjiang has a larger fluctuation range than Zhongguancun. According to 3.2 analysis, the resources occupied by Zhongguancun in the system before 2011 were basically less than that of Zhangjiang, at this time the competition coefficient of Zhangjiang was larger; after 2011, the resources occupied by Zhongguancun began to increase, the rate of increase gradually increased, and the competition coefficient was greater than that of Zhangjiang. As shown in Figure 3(d), the system is temporarily in an unstable state, and the biomedical innovation ecosystem will be far from the equilibrium state 3-c. But over time, the system will evolve to a steady state 3-a or 3-b.

Use software to fit the economic output statistics of the two science parks to get the economic output fitting curve (Figure 5).

Table 3 Score table of evolution degree of innovation population of biomedicine innovation ecosystem

Years	*Output value of Zhongguancun Life Science Park*	*Normalised processing result*	*Output value of Zhangjiang Life Science Park*	*Normalised processing result*
2006	281.2	0	52.17	0
2007	294.0	0.007067528	65.87	0.051401343
2008	378.2	0.053558611	59.02	0.025700672
2009	497.0	0.119154105	106.11	0.202378719
2010	621.6	0.187952073	129.90	0.291636964
2011	793.2	0.282701121	134.67	0.309533636
2012	1,106.2	0.455524267	146.88	0.355344614
2013	1,316.9	0.571862404	197.82	0.546467565
2014	1,430.8	0.634752360	207.76	0.583761678
2015	1,628.3	0.743802109	216.21	0.615465426
2016	1,872.9	0.878858153	222.75	0.640003002
2017	2,092.3	0.999986550	248.58	0.736915169
2018			318.70	1

Note: The 2008 data of Zhangjiang Life Science Park is missing, the value here is the average value of other years.

Figure 4 Evolutionary curve of innovation population in biomedicine innovation ecosystem

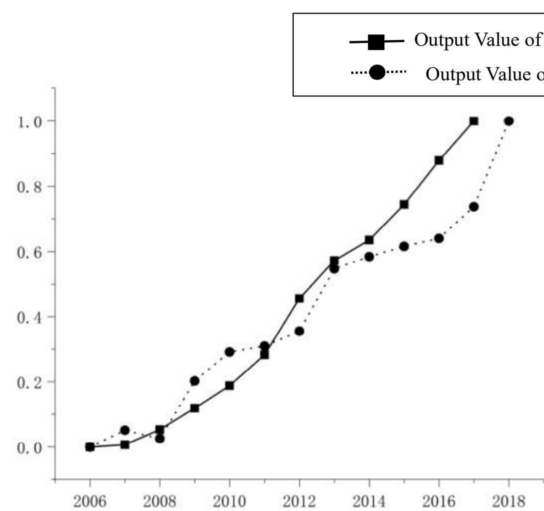
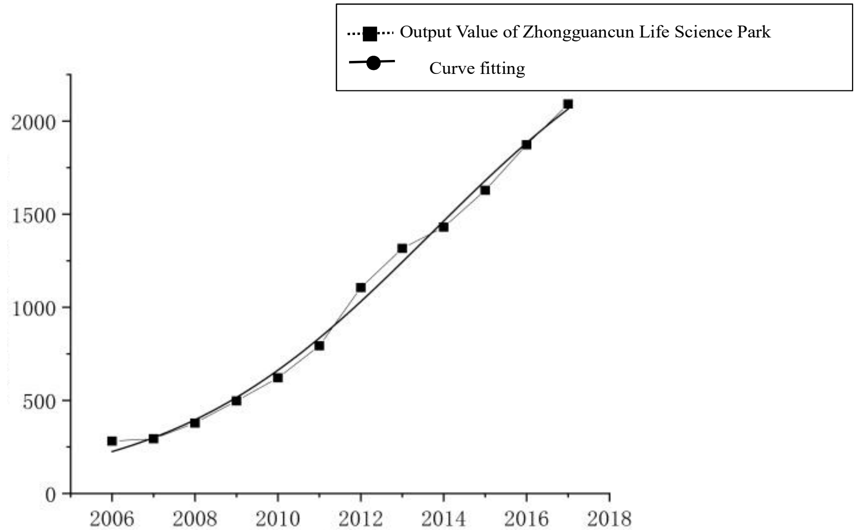
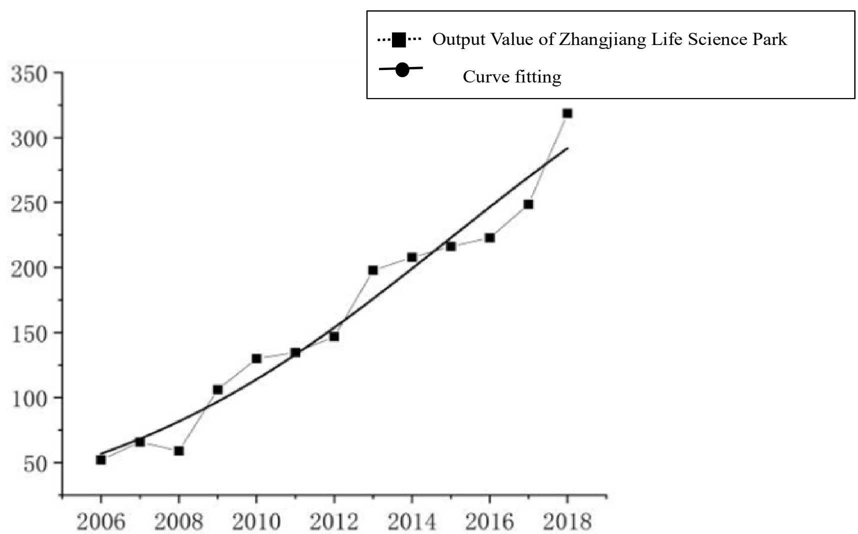


Figure 5 Population evolution fitting curve in biomedical innovation ecosystem



(a)



(b)

In Figure 5, the curve composed of scattered points represents the actual change of the output value of this two life science parks, reflecting the actual change process of the science and technology park in the biomedical innovation ecosystem. The bold solid line represents the logistic fitting curve of these two parks' evolution. Science-based innovation has a long R&D cycle, with high R&D investment during the R&D period and low returns. Therefore, the two innovation groups were still in the 'patent protection stage' of systematic development at the initial stage of the establishment of the life science park. At this time, knowledge innovation has not yet fully transform to value conversion, thus the benefits were low. In Figure 5(a), the fitting curve of the output value of Zhongguancun Life Science Park is basically consistent with the actual curve. In the fitting curve, the value-added of economic output was little before 2009, the upward trend of the curve was slow; afterwards the upward trend gradually became fast and the evolution within the system gradually has been stabilised. In Figure 5(b), the fitting curve of the output value of Zhangjiang Life Science Park is different from the actual curve, but it is basically near the actual curve with showing an upward trend. In the fitting curve, the value-added of economic output changes greatly. The Zhongguancun Life Science Park has been established earlier than the Zhangjiang Life Science Park, and its pharmaceutical technology industry has been larger than that of Zhangjiang. With its advantageous geographical location and the support of national policies, its output value is much higher than that of Zhangjiang. However, according to the analysis in Figure 4, Zhangjiang inhibited the development of Zhongguancun to a high degree before 2011. That was because Zhongguancun's development of innovative resources in the system had been weaker than that of Zhangjiang. After 2011, the use of innovative resources gradually increased in Zhongguancun, then the value created in the system of Zhongguancun has been gradually higher than Zhang Jiang. According to recent data, Zhongguancun is more competitive than Zhangjiang; but with competitive potential of Zhangjiang emerging, its developing speed is obviously faster than Zhongguancun's. In general, there is a law of coordinated evolution between the two populations, which has gradually been a stable state from the beginning to the present. The analysis shows that the evolution mechanism of the biomedical innovation ecosystem conforms to the Logistic evolution model of ecology, that is, the innovation ecosystem has a self-organising evolution mechanism. Subject to the mutual constraints between the innovation populations, there is an ecological balance relationship with a negative feedback mechanism between the evolution of the internal structure of the biomedical innovation ecosystem and the output of the system.

5 Discussion

1 As the culture medium of the innovation ecosystem, the innovation subjects need to be coordinated with the innovation environment and adapt to the environment to achieve goals. If the subject of innovation is active, which is in a favorable environment with a consummate system, the innovation will easily succeed. Since the 18th National Congress of the Communist Party of China, a great concern has been attached to scientific and technological innovations. To accelerate the pace of China's technological innovation, the government has formulated and issued a series of positive policies. Therefore, we must pay attention to the co-evolution of the environment and policy of the innovation ecosystem. In the era of intelligence, 'smart +' is setting off a new round of changes. With the continuous development of new technologies such as artificial intelligence, big data, and the Internet, information technology and knowledge management have become increasingly important. The development of an innovation ecosystem based on developed science is inseparable from these technical aids. Meanwhile, it is necessary to make good use of the development background to accelerate innovation. The two science and technology parks should make full use of the existing innovation environment, grasp the opportunities brought by 'smart +', and combine its characteristics to provide

effective insights into the future scientific development direction and biomedical application scenarios.

2 Companies, universities/scientific research institutes and other groups of producers with innovative capabilities and unique advantages in knowledge creation and scientific research, as the backbone of an innovation ecosystem based on developed science, are an important channel for the dissemination of social knowledge. And with the advent of the era of knowledge economy, enterprises need to improve their competitive advantages through continuous knowledge innovation, while the country needs developed scientific innovation to start a new journey of modernisation of the country. Under major public health emergencies, science and technology parks must play an important role in scientific innovation and knowledge diffusion, conduct knowledge innovation in a more efficient manner, accelerate knowledge flow, expand the benefits of knowledge innovation, promote the development of scientific research, and solve problems of scientific and technological development in the fields of biomedicine and medical equipment. As a national high-tech industrial development zone in China, Zhongguancun and Zhangjiang are important bases for the transformation of biomedical science and technology innovation results. Both of two play a main role in promoting the evolution of China's biomedical innovation ecosystem. However, from the perspective of model simulation, the potential of the these two participants has not been fully exploited, and their resources have not been fully utilised. At this stage, the correlation of competition and cooperation is not particularly strong. There is no R&D platform for the alliance, and further exploration is needed.

3 Science-based innovation mainly comes from universities/scientific research institutes and research-intensive enterprises. While focusing on research and development, it is necessary to emphasise the interaction between innovation elements. Enterprises should actively play their role as the main innovation body in the system, and promote deeper integration of industry, university and research. And innovation resources have to be used to enhance the overall innovation capability of the system; the ecology of scientific and technological innovation has to be improve to stimulate the motivation for scientific innovation. Through the interaction between the elements of innovation, resources are integrated and optimally allocated, so as to improve national capabilities to break through the key bottlenecks that limit the development of China's scientific and technological innovation. Biomedical science research and development platforms should actively interact with external innovation elements, actively participate in international, national, and regional scientific research activities, and be more proactively integrated into the innovation network, and spark innovation in academic exchanges. Zhongguancun Science Park and Zhangjiang Science Park should inject more vitality into the life science park, pay attention to the diversification of innovation in the park, and further promote the development of the system. The interaction among universities/research institutes, innovative services, capital operations, policies and regulations can be operated to enhance the overall innovation capability of the biomedical innovation ecosystem.

6 Conclusions

This study introduces the Logistic model to simulate the evolution of the biomedical innovation ecosystem, and takes the Zhongguancun Life Science Park and Zhangjiang Life Science Park as examples to simulate.

6.1 Theoretical contributions and implications

1 In the biomedical innovation ecosystem based on developed science, the development of the industry strongly relies on scientific research, and the innovation vitality is mainly concentrated in the 'producers' (universities, scientific research institutes, and enterprises with R&D capabilities). Those innovative activities have such characteristics of large R&D investment, long R&D cycle, and high risk. The uncertainty in the innovation process mainly lies in the 'producer' part, and the uncertainty mainly stems from the need for the 'producer' re-developing new products on the basis of scientific knowledge that has been sorted out. Therefore, in the early stage of system development (patent protection stage), the economic benefits increase slowly and the development speed is slow.

2 According to the relevant data analysis of the innovation population in the biomedical innovation ecosystem, the actual evolution trajectory of these two parks basically coincides with the Logistic fitting curve, and the development of the system conforms to the Logistic evolution mechanism; the two innovation populations---the Zhongguancun and Zhangjiang Life Science Parks in the system (Figure 5) have a symbiotic evolutionary relationship, and the evolution has slowly entered a stable state from instability. In the future, the innovation resources in the system will be fully utilised to continue to evolve; in addition, as the investment of innovation increased year by year, the economic output value has also gradually increased, and the vitality of innovation has basically maintained an upward state in the evolution process of the system.

We believe that the case studies of two life science parks provide further research directions for the innovation ecosystem based on developed science, and also a guidance for the development of major industries based on scientific innovation in the country.

6.2 Limitations and future research directions

Through the simulation results, it can be concluded that the economic output of the Life Science Park can reflect the level of scientific innovation ability and knowledge transformation ability to a certain extent, but it cannot measure and reflect the development indicators of the innovation ecosystem based on developed science. Diversified innovation subjects and friendly innovation environment are also key factors for its vigorous development. At first, future researches will explore how other ecosystem players, such as the government and public, affect the evolution of the ecosystem, and will give a deep understanding of the full meaning of the innovation environment. Secondly, single case studies have certain limitations. We will break through this limitation by exploring multiple industries that rely on scientific knowledge to develop.

In the biomedicine innovation ecosystem, populations compete with each other and cooperate with each other, which promotes overall development through competition and cooperation. The improvement of scientific innovation ability is inseparable from the promotion of innovation activities. In order to enhance the transformation of scientific knowledge and improve innovation capabilities, innovative subjects have to communicate and interact with each other in innovation activities. As a national high-tech industrial development zone, Zhongguancun and Zhangjiang should pay more attention to collaborative innovation between each other while devoting themselves to the research and development of biomedical technology, and complement each other in resources such as policies, talents, and service organisations to form competitive cooperation. A win-win situation will promote the self-evolution and sound development of the entire biomedical innovation ecosystem.

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