Research on the Construction of Model and Measurement Index System for Evolution Process of High-tech Industrial Cluster

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ABSTRACT

Emerging technologies have significant characteristics of biological species, and the evolution of emerging technology industrial clusters conforms to the evolutionary law of biological life cycles. This paper builds and derives the evolution model of emerging technology industrial cluster based on the Logistic model in bio-mathematics, and establishes a measurement index system for the evolution process of high-tech industrial cluster based on the model, so as to propose targeted management strategies.

Keywords: *emerging technologies, industrial cluster, measurement index, logistic model*

I. INTRODUCTION

Since the 1940s and 1950s, the constant development of economy and society has driven the rise at the level of science and technology. At the same time, new technologies represented by electronic and information science and technology, and life science and technology have undergone rapid development. The rapid development of science and technology has also brought the cultural life of human society into a new stage. Compared with traditional resource-based industries, emerging technology industries are more sensitive to technological innovation [1]. The essence of the upgrading of emerging technology industries is technological innovation. The evolution of emerging technology industrial clusters is an inevitable result of technological innovation. As of 2016, China had approved and established 146 national high-tech industrial development zones. This marks that China's emerging technology industry is presented in a clustered development model.

"Cluster" originally refers to a biological population living together in the same habitat; and the biological population lives in the same habitat on the basis of symbiotic relationships, so this term originally came from ecology. The research on organizational ecology made by Michael.T.Hannan & John Freeman (1977) [2] benefited from the unity in theoretical and empirical aspects, which also laid the foundation for later combination of researches on ecological populations and evolution of economic phenomena. After that, more and more studies on the evolution of industrial clusters in economy are made by using the theory of species evolution in biology. Mascarenhas (1989) [3] conducted long-term and vertical research on the strategic clusters according to the different characteristics of the three periods. The characteristics of the periods include three periods: "economic stability period", "economic growth period", and "economic recession period". He found through research that the cluster strategy is different in the period of growth and recession of economic development. It can be clearly seen that the flow rates in both economic growth period and stable period are lower than that in economic recession period. Moreover, the circulation rate between similar groups is higher than that between different groups. Jocl.A.C. Baum (1995) [4] analyzed the changes in population of telecommunication service industries by studying the establishment and failure of fax transmission service organizations. Brad P.A.Geroski (2001) [5] studied the overall dynamic change model of the cluster. Research by Jonah Auden (2003) [6] found that self-organizing system and distant thermal equilibrium system are the deep similarities between industrial system and ecosystem.

The development of emerging technology industries is dynamic, intermittent, has the characteristics of expansion, derivation and driving, and has significant characteristics of biological species [7]. The evolution and development of emerging technology industry clusters is in line with the characteristics of the life cycles. However, although most of the current researches on the evolution of industrial clusters are based on life cycle theory, they are mostly qualitative studies on mature clusters. Few researches can judge the evolution stage of a cluster by quantitative indexes. For instance, Bergman. E.M and Feser. E.J. (1999) [8] got the evolutionary course of cluster divided into four stages: potential, emergent, existing, and declining stages. H. Yamawaki (2002) [9] summarized the stage characteristics of cluster evolution by exploring the evolution and structure of Japanese industrial clusters. In the analysis by Qin Xiaming (2004) [10], the stage characteristics of cluster evolution process were used as the basis to determine the current stage of industrial cluster development and further find the stage characteristics of specific industry and the possible development direction. But these characteristics are all described qualitatively, and there is no quantitative index judgment. Chi Renyong (2004) [11] used 154 clusters in Britain as the research samples and took the life cycle theory as the basis, got British industrial clusters divided into 12 districts, corresponding to the formation, growth, mature and declining stages respectively. Xu Xiuling (2013) [12] believed that from the perspective of network evolution, the cluster upgrading stages "germination → expansion → promotion" corresponded to the ERK model of network evolution, namely "entrepreneurial network → R&D network → knowledge network". Starting from the current industrial cluster evolution model and industrial upgrade path theory, Ruan Jianqing (2014) [13] constructed a three-stage dynamic evolution model for industrial cluster including expansion period, promotion period and innovation period of the cluster. Wang Yanyan (2014) [14] made researches on the formation, development, mature, declining and upgrade stages of industrial cluster evolution and its characteristics, starting from industrial technology paradigm, and constructed an analysis framework for the evolution of industrial clusters based on theories relevant to random factors in evolutionary economics, increasing returns mechanism, path dependence, and locking. Bai Suxia (2015) [15] found studied and found that the five stages that industrial cluster basically goes through in the process of transforming into innovation cluster are the germination, growth and mature stage (germination stage of innovative cluster) of industrial cluster, the declining or transformation stage (development stage of innovative cluster), and the mature stage of innovative cluster.

The evolution of emerging technology industrial clusters has significant evolutionary characteristics of biological species. This paper attempts to use the population growth model (Logistic model) in biomathematics to study the evolution of emerging technology industrial clusters. By characterizing the characteristics of nodes in each stage of evolution, it quantitatively depicts the evolutionary stage curve of emerging technology industrial cluster, which provides a basis for judgment of the evolutionary stage of cluster.

II. THE CONSTRUCTION OF THEORETICAL MODEL FOR EVOLUTION STAGES OF HIGH-TECH INDUSTRIAL CLUSTER

The ecological evolution process of emerging technology industrial cluster can be compared to the growth model of biological species. Therefore, nesting the ecological evolution process of industrial clusters [16-17] in ecological mathematical model is helpful for making the research and analysis. On this basis, this paper uses the Logistic model in biomathematics, derives and explains the evolutionary stages of emerging technology industrial cluster.

It is assumed that $\overline{N}$ is the saturation capacity of a cluster, $\frac{dN}{dt}$ is the growth speed of the cluster, $\alpha > 0$ is the growth rate of the cluster, and N is the state variable ($N > 0$) of the cluster in the evolution process and is the function of time t. With the increase of time, the number of enterprises in the cluster, N (t), keeps increasing. When t → ∞, N (t) reaches saturation $\overline{N}$. The growth equation model of the cluster is as follows:

$$\frac{1}{N}\frac{dN}{dt} = \alpha(1 - \frac{N}{\overline{N}}) \quad (1)$$

From equation (1), the growth speed of the cluster can be got as follows:

$$\frac{dN}{dt} = \alpha N(1 - \frac{N}{\overline{N}}) \quad (2)$$

A quadratic differential is made on the growth equation, as follows:

$$\frac{d^2N}{dt^2} = \alpha^2 N(1 - \frac{2N}{\overline{N}})(1 - \frac{N}{\overline{N}}) \quad (3)$$

The quadratic differential represents the acceleration of the cluster growth. Provided that $\frac{d^2N}{dt^2} = 0$, the inflection point of the state evolution curve can be obtained. It can be known from (3) that the equation is 0 if only N = 0, N = $\overline{N}$ or N = $\frac{\overline{N}}{2}$. When N = 0, it is meaningless; when N = $\overline{N}$, the cluster reaches saturation and there is no need for the discussion. When N = $\frac{\overline{N}}{2}$, an inflection point appears in the equation curve. At this time, $t^* = \frac{1-c}{\alpha}$ and $\frac{dN}{dt} = \frac{\alpha\overline{N}}{4}$.

The growth inflection point of the entire industrial cluster is the inflection point of the curve. Before the inflection point, the acceleration of the growth speed of the cluster is greater than zero. At this time, the growth speed of the cluster is increasing. After the inflection point, the acceleration is less than zero and the growth speed of the cluster is decreasing.

The equation is solved by cubic differentiation; provided that $\frac{d^3N}{dt^3}=0$, then $N_1=0$, $N_2=\overline{N}$, $N_3=\frac{\overline{N}}{3+\sqrt{3}}$, $N_4=\frac{\overline{N}}{3-\sqrt{3}}$.

When N = 0, it is meaningless; when N = $\overline{N}$, the cluster is in saturation state, there is no need to discuss it. So only if $N_3=\frac{\overline{N}}{3+\sqrt{3}}$, $N_4=\frac{\overline{N}}{3-\sqrt{3}}$; correspondingly $t_1=\frac{\ln(2-\sqrt{3})-c}{\alpha}$, $t_2=\frac{\ln(2+\sqrt{3})-c}{\alpha}$.

When t_1, $\frac{dN}{dt}=\alpha\overline{N}\frac{2+\sqrt{3}}{(3+\sqrt{3})^2}=\frac{\alpha\overline{N}}{6}$; when t_2, $\frac{dN}{dt}=\alpha\overline{N}\frac{2-\sqrt{3}}{(3-\sqrt{3})^2}=\frac{\alpha\overline{N}}{6}$ is satisfied; at this time, there are two symmetrical inflection points on the growth speed curve, [t_1, $\frac{\alpha\overline{N}}{6}$] and [$t_2$, $\frac{\alpha\overline{N}}{6}$]. When t $\to\infty$, $N\to\overline{N}$, $\frac{dN}{dt}\to 0$. Above all, the Logistic evolution process curve and growth speed curve of the cluster can be obtained, as shown in "Fig. 1".

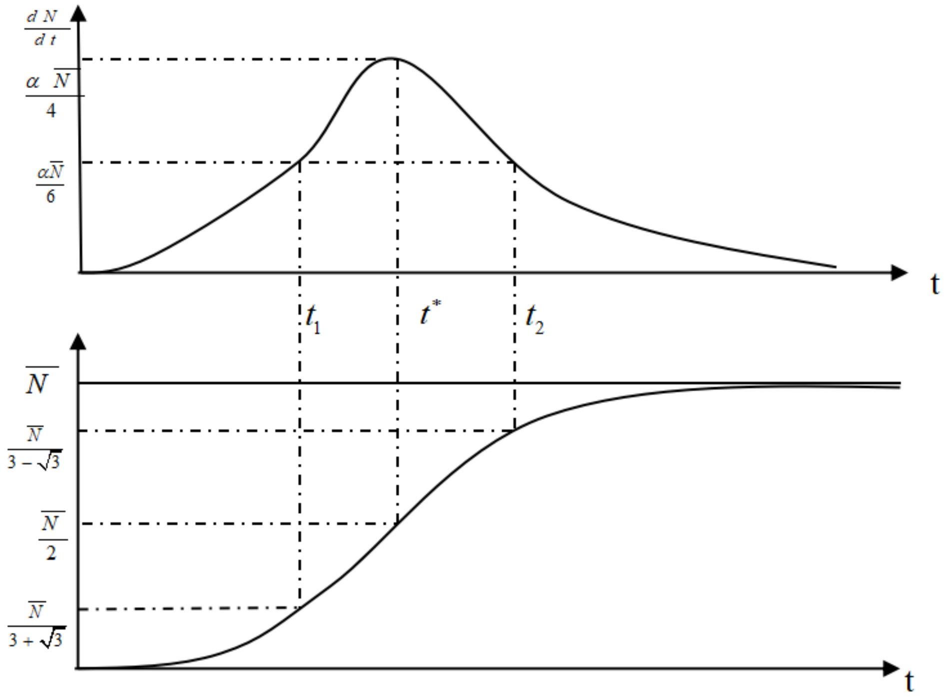

Fig. 1. Logistic evolution curve and growth curve of emerging technology industry cluster.

III. MEASUREMENT INDEX SYSTEM FOR THE EVOLUTION PROCESS OF HIGH-TECH INDUSTRIAL CLUSTER

The following dimensions are set on the basis relevant empirical literatures, and the corresponding research variables and measurement indexes are selected. The dimensions are divided into four dimensions: strength, potential, resource and environment of the cluster.

Industrial cluster is a specific unit of economic structure. It refers to the collaboration of clusters in a certain industry to achieve efficient production. As a specific unit structure of modern economy, the strength of cluster includes the scale and benefits of the cluster. Different size of cluster will bring different economic effect accordingly. The specific manifestation of industrial clusters is the highly specialized division of labor and cooperation carried out by different enterprises in a cluster for an industrial task. Different enterprises have different roles in the entire industrial chain, and the division of labor and cooperation is specialized and streamlined. In this specialized and streamlined production activity, the efficiency of cluster production is very high. Some small and medium-sized enterprises cannot obtain large economic effects internally due to problems such as costs, namely the internal scale economies effect is small. Through industrial cluster, these small and medium-sized enterprises take cooperation as a bridge to conduct external collaborations with other enterprises, thereby achieving effect of scale economy. In this case, these companies can not only free from undertaking the risks brought by its scale and scale limit but can also realize a leapfrog development. In the process of industrial clustering, especially when homogeneous industries are clustered, vertical connections can be used to open up business relationships between suppliers and customers to achieve resource interconnection. Within the horizontal scope, industrial clusters can help companies mobilize more resources to achieve the optimal allocation of resources and improve production capacity and product quality. Therefore, according to the effect of "1 + 1> 2" created by the strength of the cluster, this paper considers that the scale of a cluster can be determined by the number of enterprises in it, and the effect of clustering should be specifically measured by the net profit.

Industrial cluster emphasize the construction of an innovation system through the deep integration of production, learning and research to promote the further development of industrial innovation. Making an evaluation on the potential of an industrial cluster can effectively help to enhance the coordination and coupling capabilities in the process of industrial clustering. The potential of cluster includes technological innovation capability of the industry and industrial equipment of the cluster. At present, with the rapid development of economic globalization, cluster innovation capability is an inevitable requirement and trend of the economic and social development. This capability mainly depends on the coordination and innovation activities conducted by regional high-tech enterprises and related research institutes and universities in specific regions; in addition, related suppliers and service organizations working in clusters in the same region also provide strong support for cluster innovation activities. Clustered organizations and units can form different functions and homogeneous value industrial chains, interacting and playing the role of network clusters. The proportion of concentration of cluster industrial equipment will also potentially affect the potential played by the cluster. Therefore, it is particularly important to pay attention to the application of R&D results of colleges and universities and the investment in scientific research projects of various scientific research institutions. Fund support for scientific service also becomes very important. Therefore, this paper uses R&D fund to measure technological innovation capabilities and net fixed assets to measure cluster industrial equipment.

The technical talents in enterprise, the proportion of relevant specialized talents in scientific research institutes and universities in a cluster area, the innovation efficiency of talents, and the thinking orientation will all affect the use of cluster resources. Therefore, personnel engaging in scientific research can measure the characteristics in human resources. Cluster resources also include intangible assets such as the regional brand image of an enterprise. First, the higher the level of regional economic development is, the greater the potential of the industrial cluster is, and the level of economic development in the region will also stimulate the purchasing power of people in the region. Besides, the proportion of the industry's investment in the nationwide will also affect its regional brand image.

The cluster environment includes the hard environment of investment and government support; in fact, the two aspects both cannot be separated from the government's emphasis on the industry and relevant support policies; because industrial clusters depend on the support of financial, legal, and commercial service agencies Support and whether the government can give preferential policy to the region in terms of service industry and create a good business environment for the development of enterprise clusters. Therefore, this paper believes that the amount of infrastructure investment can be used to measure the hard environment of investment for the development of industrial clusters, and government support can be considered by the investment of funds from government departments.

IV. CONCLUSION

The essence of emerging technology industrial cluster evolution is the innovation and upgrading of emerging technologies. Emerging technologies have significant characteristics of biological species. Based on the Logistic population growth model in biomathematics, this paper constructs and elaborates the model of evolution stages of emerging technology industrial cluster. On this basis, the Logistic model is used to analyze the evolutionary stage of the cluster from four dimensions (the strength, potential, resources and environment of the cluster).

Based on the Logistic model, a measurement index system for the evolution process of the cluster is summarized; combined with the characteristics of the emerging technology industry, a regional development plan is formulated, and supporting priority is given to the scientific and technological fields, and different types of enterprises in the cluster are classified to support project establishment.

First, for large and medium-sized enterprises dominant in the cluster, the science and technology management department should guide them to take the initiative to undertake the establishment and application of major scientific research projects through scientific research support plans and high-tech industry development plans. The department should also encourage production-university-research alliances, encourage them to actively expand technology fields and markets, and improve the industrial chain structure.

Second, for small-sized innovative enterprises in the cluster, the department should set up corporate incubation policies, torch plans, innovation fund assistance, etc., to improve corporate innovation capabilities, and promote enterprises to become bigger and stronger.

Third, it is needed to continuously improve infrastructure construction, build a complete science and technology service system including the carrier, platform, funds, technology and talents for the service, perfect the soft and hard environment of the cluster, promote the development of emerging industries in the cluster, improve the technology innovation level of the cluster, and boost the cluster to transit and upgrade to mature period.

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