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Research on Driving-Forces of Industrial Cluster Formation from the Perspective of Population Competition and Interdependence

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***Abstract*—Population Ecology provides a new way of thinking on the theory of industrial clusters. By comparing ecosystems and industrial clusters, the ecological property and behavioral characteristics of industrial clusters are revealed. The generally formative process of industrial clustering is described from the perspectives of population competition and interdependence, and the driving-forces of industrial clustering formation are analyzed and identified in terms of internal conditions and the external environment on the basis of an expansive model of the Logistic equation. A case of Sinos Valley of Brazil is given to show the process of the formation of industrial cluster from the Perspective of Population Competition and Interdependence.**

Keywords—industrial cluster; population competition and interdependence; Driving-Forces of Formation; Logistic model

I. INTRODUCTION

Industrial clusters widely exist in reality as an economic phenomenon, and there are a lot of industrial clusters which have made remarkable success around the world. With the ever-accelerating process of globalization, a notable phenomenon emerges. The production and operation of enterprises are not made to be spatially balanced by globalized production, but geographical concentration of production activities has been enhanced. As M. E. Porter pointed out, economic map of the world is filled with regions known as clusters today [1]. Industrial clusters show clear advantages in the fierce competition in the market, achieves enormous economic benefits, and promotes development of the regional economy and even the country's economy.

An industrial cluster refers to the geographical focus of related enterprises and institutions in a specific area, which include a series of interrelated industries and other social factors significantly influencing the formation and evolution of the industrial cluster [1]. Industrial cluster is a typical situation in the process of economic development in the world, and also a hot issue in the study of economic theory.

II. BACKGROUND

Industrial cluster theory originates in agglomeration economic theory, and can be traced back to Alfred Marshall initially, who considers that the expanding of industrial scale would promote an increase of industrial knowledge and the dissemination of technical information, which led to the formation and development of industrial clusters[2]. Michael Porter investigates the formation of industrial clusters in the view of new competition economics. In his view, an industrial cluster is first composed with one or two innovative enterprises, which will stimulate the growth of many other similar enterprises. Once an industrial cluster begins to form, the self-reinforcing mechanism will promote its growth. Businesses, governments and various institutions that are related to each other closely play important roles in forming an industrial cluster. The relationship between business and government, public and other agencies will be increasingly clear with the development of an industrial cluster. Competition and cooperation among participants can be upgraded at the same time within the industrial cluster, which can also promote its evolution [1]. Many useful conclusions about industrial clusters can be drawn from the economic perspective, but there are still a lot of non-economic factors which will impact the process of formation of an industrial cluster, such as social systems, corporate culture and subjective perception.

Population ecology is applied into organizational management by Hannan and Freeman, who found the theory of organizational ecology [3]. The basic proposition of the population ecology of an organization is that the survival of an organization is decided by adaptation of its type or form to the environment, which emphasizes on three processes: variation, selection and retention. Variation refers to innovation in organizations; selection refers to appropriate organizations selected by the environment; and retention refers to the survival of organizations, these are also the three stages of natural selection [4]. Among them, the environmental selection is the most important stage, which determines the basic elements of survival. An organizational population is the collection of organizations depending on the same physical and social environment and relying on common resources, and the adaptability and survival of organizations depend primarily on organizational form selected by the environment [5]. The direct and indirect impacts of an enterprise's entry, exit and changes in market structure can be effectively explained by the theory of population ecology [6]. The concept of the ecological market is put forward by Ken Baskin, who explains the basic power of business development based on confused and complex ecosystems of the nature [7]. Ecology Population Theory is

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used to discuss the confliction and collaboration within organizations by Daft [8]. Hannan and Bigelow study the evolutional process of the automobile industry of the United States and Europe separately [9][10][11], and they prove that the geographical environment have different effects on the legalization and competition of populations which can be used to explain the imbalance of industrial evolution and geographic distribution. Gambarotto and Maggioni investigate the effects of government policy as a very important factor on industrial ecosystems with the theory of r-k strategists in population ecology [12].

Application of population ecology is also extended to other aspects, such as the life cycle of organizations [13], the life-cycle stage models [14] and the relationship between technology development and organizational environment [15].There are ground-breaking insights to study complex problems related to industrial clusters in the view of ecology, which will not only enrich the study of ecology, but also broaden the scope and thinking mode of the traditional theory of industrial clusters.

At present, the focus of study about industrial clusters is on the fact that an industrial cluster has highly competitive abilities and clear advantages, but how does it form? Does an industrial cluster having strong competition forms spontaneously or relies on government nurturing? In fact, it is similar to ecosystem.

III. ECOLOGICAL PROPERTY AND BEHAVIORAL CHARACTERISTICS OF INDUSTRIAL CLUSTER

A. Ecological property of an industrial cluster

In the field of ecology, there are four different levels in the biology groups: species, population, community and ecosystem. A population is composed of a group of species; a community refers to the group of all populations in a particular habitat; and the ecosystem is s system composed of biological communities and the natural environment. Compared to bunching relations among different species in the natural world, an industrial cluster also has a variety of organizations of different forms and nature, which are closely related to each other. The organizations form a co-existent social network system with interactive relationships of interdependence, competition and cooperation. In the view of population ecology, an enterprise is like a species, enterprises with similar technology and techniques in the same area constitute a population, closely related enterprise population congregate to be an industrial cluster, and industrial clusters and their environment constitute an ecosystem. The comparability of an ecosystem and an industrial cluster system is shown in table 1.

B. Behavioral characteristics of an industrial cluster

The ecologically behavioral characteristics of an industrial cluster can be recognized in the comparison with an ecosystem, which are mainly reflected in the following areas:

1) The relationship between different enterprises

In the formative and evolutionary processes of biological communities, different organisms often share food, realm, information and other resources for the sakes of individual development and community needs, and then different relationships are formed. Based on the theory of population ecology, different inter-firm relationships can be deduced, which are theoretically doable. Population relationships in ecosystems primarily include competition, predation, parasitism, neutrality, symbiosis, mutual benefit, partial benefits, partial harm and so on. Industrial clusters with the core of interdependence and competition also have the similar relations as ecosystems.

2) Niche

Niche is an important concept in modern ecology, which refers to a distributional unit inhabited by species in the ecosystem [16]. In the long term of survival competition, each species has the most suitable space-time location for its survival and functional relationships with other species. The niche not only embodies the contact with other species in the community, but also reflects the interaction with the environment [17]. Every enterprise can only occupy a certain location of the ecological resources space at a specific period, and the occupied part is its niche. In a cluster region, enterprises taking up different niches receive different benefits. The competition among enterprises reflects the string for niche. Enterprises achieve self-development through metabolism, cluster and integration, innovation and change to adapt to the environment.

3) Bionomic strategy

Bionomic strategy is also known as life history strategy, which refers to the act modes under certain ecological stress in the process of biological evolution and the evolution strategies are taken by creatures to adapt to the environment. Scientists divide creatures into two categories of r-strategists and k-strategists in accordance with habitat, environment and evolutionary strategies [18]. In the competition for survival, the k-strategists who use most energy to survival depend on "quality", while the r-strategists using most energy to breed rely on "quantity". This principle also holds true in the evolution of enterprises. The r-strategists are enterprises possessing specialized technology and low-cost advantages. They usually succeed depending on scale, but their competition barriers are relatively lower and easier to be overcome. The enterprises of k-strategists with strong and unique core competencies, have relatively lower reproduction rates, adapt to circumstances flexibly, and cannot be copied easily. Companies are forced by the environment to improve strategic modes and complete the transformation from r-strategists to k-strategists.

4) Co-evolution

There is an effect of factor compensation in the natural ecosystem, which refers to the fact that the biological species adapt to environmental changes by mutual adjustment, and the overall level of the environment will be restored or enhanced through the function of complementary and alternative species. In other words, the evolution of an ecosystem is the result of the co-evolution of its biological species. The evolution of a species may change the selection stress of other creatures affecting their adaptability, which will cause further changes in related species. Therefore, the evolution of two or more organizations is usually interrelated, and an interactive co-evolution system is formed. Co-evolution of industrial clusters

is an objective phenomenon, and which will promote the development of enterprises. Like the co-evolution among species in the natural ecosystem, co-evolution of industrial clusters not only happens among competitors, but also non–competitors (predators, parasites, and the food chain). Cooperative competition is a distinctive feature of formation and evolution, and the ultimate purpose is to reach the cooperative development of all enterprises in the cluster.

However, the co-evolution processes of industrial clusters have differences from the natural ecosystem. First of all, the formation of new species in natural systems often needs a long time, while enterprises can evolve several times when adapting to changes in the market. Secondly, the industrial cluster has its own ability to control the direction of evolution, but the biological evolution is the process of natural selection. Third, the co-evolution of an industrial cluster is developed by cooperation. Fourth, the competitions in the process of co-evolution aim at the leadership in the clusters.

TABLE I. THE COMPARISON OF THE ECOSYSTEM AND INDUSTRIAL CLUSTERS

Scope		Ecosystem	Industrial Clusters System
System Levels	Species	Organism (creature)	Enterprise
	Population	Aggregation of the same organism (creature)	Aggregation of enterprises with the same property
	Community	Aggregation of different populations	Aggregation of different enterprise Communities
	Ecosystem	Interactive system composed of communities and the environment	Interactive system composed of enterprise populations and the environment
Structural Similarities	Systemicity	The components interact with each other and an extremely accurate and comprehensive system, which utilize materials and energy efficiently, is formed.	Enterprises, government, intermediary agencies and the natural ecosystem constitute a system and the corporations in the cluster are greatly affected by other components.
	Periodicity	The development processes consist of growth, differentiation, existence, senescence and death.	Industrial clusters also experience investment, growth, maturity and decline.
	Nutrient Structure	Food chain/Food net	Industry chain/Value chain
	Feedback Characteristics	Positive /Negative feedback	Positive /Negative feedback
	Environment Characteristics	Natural selection, adaptability	Survival of the fittest, acclimatization
	Relationship	Competition, interdependent, symbiosis and etc.	Competition, interdependent, symbiosis and etc.
Functions		Energy flow, material cycle, information transmission, value circulation, biological production	Material flow, information transmission, value circulation, production activity

IV. GENERALLY FORMATIVE PROCESS OF INDUSTRIAL CLUSTER

At the formation stage of a biological community, some species diffuse to a certain habitat and show survival advantages after the process of settlement and competition. Then population carrying the advantaged genes begins to form and the community emerges because of aggregation of other related species. The formation of an industrial cluster has similar characteristics. A number of organizations or enterprises diffuse to a certain region and show some advantages in competition, and the advantaged species are formed. Related enterprises begin to gather, but the aggregating speed is still low and an industrial cluster has not yet formed completely. The formation of an industrial cluster can be expressed as the growth of cluster scale directly. So we can obtain the formative trajectory of an industrial cluster from the number of enterprises entering and exiting [19].

The formation of an industrial cluster is a process of legalization, which is the combined result of agglomeration and crowding effects. The legalization process refers to that, at the early stage of industrial cluster, the organizational form and products or services of enterprises cannot be accepted by the public because of economic, technical, culture, habits and other factors. But an industrial cluster will be gradually accepted by the public with the improvement of the quality and performance of the products or services, technical progress, extensive publicity by the enterprise, and the role model of vanguard consumers. The density of an industrial cluster increases legitimacy when it is low. In other words, the initial legalization is enhanced because of more companies entering the industry cluster. But benefits of the enterprises decline with increasing density. The generally formative process of an industrial cluster can be described by Fig. 1.

V. DRIVING-FORCES OF INDUSTRIAL CLUSTERS

A. The model

A cluster is a kind of adaptable feature of an ecosystem. Most of the individuals of the biological population do not exist in isolation; and the distinct individuals of the homogeneous population would live together in a certain period. But some social creatures with the characteristics of division and cooperation will exist only by connecting with the homogeneous species and other individuals. A cluster exists wildly in nature as an adaptable feature and is an important way to ensure existence and regular multiplication of population. The positive value of biological aggregation lies in that the congregation would enhance predatory efficiency, defend common enemies, change niches, promote propagation and improve learning efficiency. Cluster effect would be exits only when there are sufficient participants. The individuals would lead to extinction if the number is too small or below the limit, which is called “the smallest group principle”. Many scholars believe that the external economy is the main source of competitive advantages of an industrial cluster. External economy depends on spatial agglomeration of substantially relative enterprises, and larger scale of output. The driving-forces of the formation of an industrial cluster are analyzed in this paper based on an expanded Logistic model [20].

$$r(t-t_0) = \ln\frac{N}{N_0} - \ln\frac{\overline{N}-N}{\overline{N}-N_0} + \frac{\overline{N}}{\overline{\overline{N}}}\ln\frac{\overline{N}-N}{\overline{N}-N_0} \qquad (1)$$

There are three basic parameters in this model which are the ideal cluster size $\overline{\overline{N}}$, saturated scale under specific environment $\overline{N}$ and relative growth rate r. In addition, t expresses the time, N_0 is the scale at the initial time t_0. $r(t-t_0)$ on the left side of Eq. (1) can be seen as the relative growth of cluster scale from t_0 to t. And the right side of Eq. (1) consists of three terms. $\ln(N/N_0)$ is the natural growth rate of Malthus, the second term refers to relative growth under constraints of saturated resource in specific circumstances, and the third term has a coefficient $\overline{N}/\overline{\overline{N}}$ between the range of 0-1 compared to the second term, which represents the impacts of resources on clustering or the degree of utilization of the environment. If $\overline{N}/\overline{\overline{N}}=0$, the environment plays the greatest impact on the industrial cluster and Eq. (1) equals the traditional Logistic equation; when $\overline{N}/\overline{\overline{N}}=1$, environmental expresses impact on the industrial cluster at the lowest level, which returns to the Malthusian model. By Eq. (1), we can see that the size of industrial cluster is an increasing function of $\overline{N}$ in a certain period, and with the growth of $\overline{N}$ the degree of resource utilization and growth rate of cluster scale will be improved. But the survival of new resources can be developed with the development of technology and productivity, and the $\overline{N}$ will increase. The formation and development of industrial cluster is the process that $\overline{N}$ constantly approaches to $\overline{\overline{N}}$.

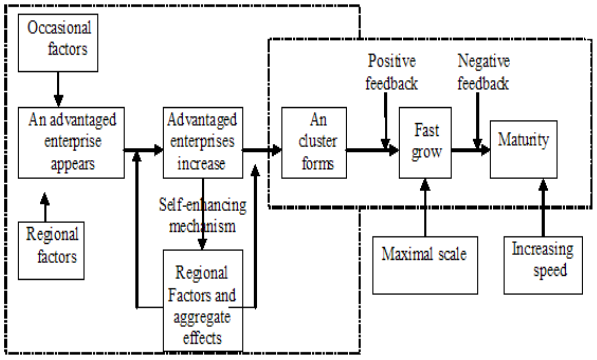

Figure 1. The formative process of an industrial clusterInternal conditions

From the perspective of ecology, formative power of an industrial cluster comes from its internal structure, including two aspects: composition structure of its industrial populations and relationship of competition and interdependence within the cluster.

1) Composition structure

From the composition of species within the cluster, if the relevance and complementarity are stronger among the species in the cluster, the clusters formed have more advantages. On the contrary, as ecological communities, if the industry cluster has only competition without complementary relationship among the species, the cluster may have difficulty coordinating development and will likely eventually decline. The elements of species within the industry interact among each other through some reasonable distribution and coherence supplemented by the corresponding external conditions, industrial species reach a certain threshold, and a "field effect" is formed [21]. There are three functions. The first is the function of polarization, or absorption and concentration function, which is that the regional advantage attracts the enterprises out of the regional. The second is the extended function. On the one hand, spatial scope is growing constantly with the quantity of similar enterprises of the region increasing. On the other hand, the industry chain of the enterprise is constantly extending and the scope of the population is constantly enlarging. The third is the self-organization function. The industrial cluster is an approximative ecological organization, which has self-developing, self-replicating, self-derivative functions. With field-effect, the formation of industrial clusters results in a hierarchical form spanning from the lower-level to the advanced level. (Individual - Industry species -Industry cluster).

2) Relationships within a cluster

From population's sibship among the industrial cluster, the colonies among population's competition and the interdependence relations can promote the enterprise's cooperation and innovation. Moreover, the interactions between the outside enterprises and the other related colonies are also important factors for the improvement of the industrial cluster. Taiwan Hsinchu science and technology garden's development benefits from this relationship [22]. The enterprise is the main body of forming the industrial cluster. Any industrial cluster has the competitive ability inevitably to take the enterprise's competitive ability as a foundation. In the pursuit of competitive advantages, the enterprise inevitably has massive interactive relations with other cluster's individuals and the population. This kind of interactive relations and the effect will affect and have decided the industrial cluster's formation in many aspects.

An industrial cluster can meet the expansion needs of the business niche. The niche that enterprises occupied in a certain period of time is limited to a cluster saturated scale in a specific environment, that is, the larger the scale, the greater the niche breadth. The essence of business is to pursue greater profits. The niche breadth is a key to the interest that the enterprise can get. Based on the needs of niche development, competition and interdependence are formed between enterprises and enterprise clusters, while competition is based on the premise of interdependence. This kind of interior interactive relationship is the foundation to exert its pull-out effect [1]. It expanded the scope of agglomeration effects for the enterprises and provided a new space for the development of enterprises and industrial clusters.

An industrial cluster is a selective result of ecological strategy, and the selection is designed for enterprises to improve the utilization of environmental resources represented by the coefficient $\overline{N}/\overline{\overline{N}}$ in Eq. (1). Because of limited

resources and an increasingly competitive market, the requirements of survival and development cannot be met by competition simply, and enterprises are forced to improve their strategic model by environment. The emergence of industrial clusters is the result of enterprises' ecological evolution and selection of strategy. Enterprises take full advantage of the regional infrastructure, service facilities, resources and market information networks and a specialized division of labor system can be formed based on competition and interdependence within an industrial cluster, which will exert advantages of r- strategies—low cost and professionalism or K-strategies—innovation.

B. External environments

External dynamics is the external environmental factors and habitat. The external environmental factors of the formation of an industrial cluster include the original resources, infrastructure and financing channels, the system of human environment and other factors. These are location factors.

1) Original resources

The original resources which are linked with industry closely are essential to the formation of industrial clusters. It is also the determinants of the relative competitive advantage factors obtain by the enterprises when the clusters formed at the beginning. Because of the existence of original resources, the enterprises settle in a particular region. Different types of industrial clusters have different original resources, such as labor costs, technology, product characteristics, raw material quality and other advantages.

2) Infrastructure and financing channels

Public facilities such as regional transport and communications impact the flow of resources. The industrial agglomeration areas often have convenient transportations and advanced communication service and other comprehensive public services. Unblocked and high efficient financing channels play an important role to the formation of industrial clusters, especially in the formation stage of the cluster, the most critical risk investment.

3) Humanistic environment

The healthy development of industry clusters depend on a reasonable institutional arrangements. At the same time, the formation of clusters is related to geographical and cultural backgrounds, population and even religious values, the family values, education concepts, economic concepts, the consciousness of accepting the challenge and adventure pay profound influence on the industry clusters.

C. Case analysis

In the 1930s , most people engaged in small-scale agriculture or handicraft production in Sinos Valley of Brazil. Based on the handicraft industry, enterprises of shoe-making appeared in the 1940s. To the late 1960s, a mature industrial cluster was formed by small and medium-sized enterprises. There were more than 400 shoe-making enterprises and many public and private sectors provided specific services to support economic activities of the cluster such as training, technical supporting and sales services. At this time, the cluster was composed mainly by the aggregation of small and medium-sized enterprises in space, and had a high degree of vertical specialization and closely vertical or horizontal linkages of competition and cooperation between firms. From the 1970s to the late stage of 1980s, the industrial cluster entered a rapid growth period due to the export-oriented business measure. In 1969, the Brazilian government implemented policies to encourage exports, and at the same time, the proportion of total imports in total consumption of the United States increased from 20% to 80%. The industrial cluster of Sinos Valley attracted many importers from the United States by specialized division and production systems. At the same time, enterprises in the cluster also took collective actions: sending samples to the trade fairs in the United States and European, organizing exhibitions in the local and inviting foreign buyers and foreign magazine to participate, publishing ads to promote their products in foreign newspapers. In this way, the cluster entered the U.S. market and expanded the market scale significantly within twenty-five years. By 1991, there were more than 1800 enterprises with 15 million workers in the cluster, and 70 percent of products were exported to the United States. The total production of the cluster accounted 30% of the total production of shoes and more than 80% of the total exports in Brazil. In the twenty-five years, the structure of the industrial cluster, the scale and producing mode of enterprises in the cluster and the business relations among enterprises had great changes. Firstly, large enterprises appeared in the cluster, and they adopted standardized production methods of the Ford system to produce a large number of products; Secondly, the export agents became the core of the cluster.

The rapid growth of exports suddenly stopped in the mid and late 1980s that mainly because of the competition from low-wage countries such as China. In the late of twentieth century, the Chinese products began to import into the U.S. market and competed with the Brazilian products in the low-cost and standardized shoes market. At the same time, the U.S. market also changed. In order to reduce inventory costs, retailers reduced the number of products of each batch and called for shorter delivery time and higher product quality. In this case, the growth rate of the industrial cluster slowed down and its internal structure and relations also changed. First of all, the number of large enterprises decreased. The production mode of the Ford system could not adapt to the new competitive environment. Secondly, the enterprises depend less on the export agents. Some large enterprises changed the business mode to sell products to European bypass the export agents, and other enterprises became a center for business development by organizing production as the export agents. Thirdly, the relationship among enterprises became more closely. Due to the demands of higher flexibility and quality, the relationship between many enterprises and contractors changed from the "keep distance" to the close contact. The cluster got steady growth after structural adjustment.

According to the description above, the growth curve of the industrial cluster in Sinos Valley can be drawn (Fig.2). The industrial cluster begun to take shape in 1940s, gained a rapid development in late 1960s and then entered a mature stage with a strong concentration effect and competitive advantages. In early 1970's, the cluster entered a new market - the United States, because of the policies of Brazilian government and

changes in demand for the U.S. market. The size of the market demand had a sharp increase with a rapid climb of $\overline{N}$, and at this point, the developing curve of the cluster deviated from the original track to the other Logistic growth curve with steeper and higher peak. Due to the influences of economic globalization and fierce market competition in the mid-and late period of 1980's, the market demand of the cluster decreased rapidly, resulting in a slower development of $\overline{N}$ and a more flat logistic curve. But in the early nineties, the industrial cluster's structure changed under the pressure of competition. The specialized collaboration network was improved and the relationship among enterprises became more closely, so that the cluster development gained a newly growth with a rapid rise of r and a steep Logistic curve.

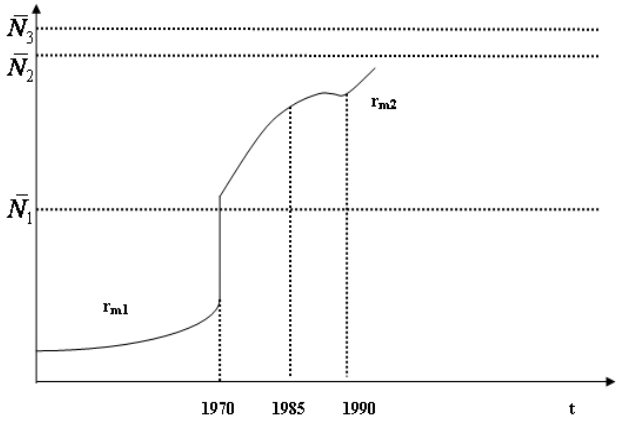

Figure 2. The logistic curve of the industrial cluster in Brazil

VI. CONCLUSION

Population ecology provides a new way of thinking in the study of industrial clusters. Industrial clusters show strong similarities with ecosystems from aspects of system levels, structure and functions, and also have ecological behavior of population relationship, niche and ecology strategies. Competition and interdependence among populations play an important role in the formation of industrial clusters, and constitute the inherent power of formation, which meet the requirements of niche expansion of enterprises, and also the result of evolution and ecological strategies' selection. At the same time, location factors of industrial clusters also affect the formation of industrial clusters significantly, such as original resources, infrastructure and financing channels, humanistic environments and other factors.

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