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Research on formation and development of circular industrial clusters and innovative networks

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Abstract

This article analyzes and studies the forming and evolutional process of the regional industrial clusters by using the Self-organizing theory of complexity systems and synergetic method. The forming and the evolution of regional industrial clusters generally go through several phases as follow: enterprise groups, Industrial clusters and circular innovative networks. The reasons that some industrial clusters degenerate, decline and even die out are that the self-organization synergetic mechanism in clusters can't play its role and can't form high-efficient and orderly self-organization system. Only by developing a well environment condition, adjusting and controlling industrial field (institutional niche), mobilize and exert the competitive-synergetic self-organization mechanism in clusters, we can make the clusters evolve and upgrade to higher level and achieve sustainable development.

Keywords: Enterprise community, Industrial clusters, circular Innovative networks, Evolutional mechanism, Self-organized mechanism

1. Introduction

Nowadays, it is impressive all over the world that industrial clusters show unique competition superiority, outstanding vigor and strong impetus effect for the regional economy. Researchers in many fields research industrial cluster phenomenon by different views [1-3].They find that the industry with competition advantage often all have obvious regional characteristics and industrial cluster backgrounds.

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In recent years, the burgeoning of industrial cluster has more and more aroused widespread interest. Some underdeveloped areas and developing countries have used the development strategy of cluster and promoted their own competition capability [4].The results show that a successful healthily industry cluster will usually go through several stages: enterprise community, industrial cluster, innovation networks [5].With the popularity of eco-environmental awareness and the shortcomings inherent in industrial clusters, and the emergence of circular economy, which make innovative network evolution to circular industrial cluster. However after many reality agglomeration economic system develop into a certainly stage it stops developing and evolving further, and appears decline, shrink even wither away. Consequently, it is significant that study the regional industrial clusters development and evolution law, the regional innovation networks formation condition, make the cluster effect maximize and keep the lasting competitiveness for a long time. In this article we mainly concentrate on exploring the rule of development of regional industrial cluster and evolution mechanism, from the self-organization synergetic theory and non-linear random dynamics perspective [6].

2. The Formation of Enterprise Community in a Certain Industry Niche

Forming enterprise community needs certain industry niche which is the sum of different conditions (similar to such the necessaries for plant growth as soil, air, sun light and water) in particular space in a social economic ecosystem [7].Another condition is a core of industrial agglomeration that is a kernel in initial stage of enterprise community forming (equivalent to seed and plumule of the plant). It can produce enough "field effects" and cluster function to relevant enterprises when its “volume” (scale) reaches a certain threshold. In terms of the enterprise community’s generation process, a certain industry core of industrial agglomeration usually appear in the region where there are suitable industry niche. The industry field F produced by the core will form an aggregation potential V in this scope. If the field reaches to the critical value F_c, some peripheral relevant enterprises begin to agglomerate and transition in this area, thus form gradually enterprise community.

If we show the community’s output rate (it reflects the order degree of community's industrial structure) with $X(t)$. $X(t)$ is non-linear variety with time，and equal the nonlinear function $f\left(X(t),t\right)$. The variety course of a population can be described with the following Logistic equations[8].

$$\frac{dX}{dt} = f(X) = \alpha X - \beta X^2 = X(\alpha - \beta X) \qquad (1)$$

It has the following solution: $X = \alpha/(\beta + Ce^{-\alpha t})$ (2)

In which the C> 0 is integral constant determined by initial regional production rate (The number of enterprises), here $t = 0$, $X_0 = \alpha/\left(\beta + C\right)$, if $t \to \infty$, $X \to \alpha/\beta$. The result is that the enterprise community output rate (Community scale and order degree) is limited in certain area; it means that if enterprise community develops to a certain period it will tend to saturation.

3. Disorderly Competition Cause Enterprise Community Recess

Since the enterprise is impacted by external disturbance and internal fluctuation, and its running state has rather big random, state x is a random variable. Suppose the entire community constitute by n subsystems, according to synergetic method and nonlinear dynamics theory, the state change of entire

systemcan describe as a following group of nonlinear stochastic dynamic equations (Generalized Langevin equation)[6]:

$$\dot{x}_i = \frac{dx_i}{dt} = K_i(x_1, x_2, \cdots, x_n) + \Re_i(t) \quad (i = 1,2,\cdots,n) \tag{3}$$

In which x_i is the i subsystems state variables, K_i is a nonlinear function, $\Re_i(t)$ is the i subsystems random force (fluctuation and perturbation). (3) can be regarded as a group motion equation of the nonlinear damping oscillator. For simply discussion, we omit the random force, and expand K_i with multi-variable near the stationary state point, obtain

$$\dot{x}_i = \sum_{j=1}^{n} \alpha_{ij} x_j + f_i(x_1, x_2, \cdots, x_n) \quad (i = 1,2,\cdots,n) \tag{4}$$

Where, $f_i(x_1, x_2, \cdots, x_n)$ are nonlinear functions. As the stationary state spot is stable, (4) linearity coefficient matrix (α_{ij}) is the negative, that is, there is always a certain kind of linear transformation to introduce group of new variables $\{y_1, y_2, \cdots, y_n\}$, and make ($\alpha_{ij}$) diagonalization. At this time we get

$$\dot{y}_j = -\gamma_j y_j + g_j(y_1, y_2, \cdots, y_n) \quad (j = 1,2,\cdots,n) \tag{5}$$

In which, $\{g_j(y_1, y_2, \cdots, y_n)\}$ is a group nonlinear function related to all subsystems state variables, damping coefficient $\{\gamma_j\}$ will be variation with external conditions influence. Analysis shows that, before the systemreached the critical threshold value of self- organized synergy, $\{\gamma_j\}$ are not 0 positive. According to equation set (5), the subsystems compete disorderly with each other, their movements both interrelated and disorderly. If random factor is taken into account, the system can only make random fluctuations. That is, in this period enterprise community does not have cluster effect.

4. The Community's Orderly Synergetic Competition Forming Industrial Cluster

Since a system regional enterprise community is a nonlinear complex system, only formed a highly ordered structure of the self-organization, the system are features in highly efficient and order [6], then the entire enterprise community becomes a real industrial cluster.

From the synergies theoretical view, the state variables $\{y_1, y_2, \cdots, y_n\}$ in equation set (5) include the order parameter X which will guide the enterprise community developing. if the external environment change causes system's control parameter tends to some self-organization critical threshold, the order parameters X will compete to win out, and appear a " the critical slowing down ", its damping factor γ tend to zero. Yet the general, can make $y_1 = u$, so $y_1 = X \quad \gamma_1 \to 0$ (6)

Others $\gamma_i > 0 (i = 2,3,\cdots,n)$ and limited, In addition to X is soft mode variable, the others $y_2, y_3, \cdots, y_n$ are hard mode variable. In accordance with the principle of coordinated control, all hard mode variables can be "adiabatic approximation", that is

$$\dot{y}_i = 0 \qquad (i = 2,3,\cdots,n) \tag{7}$$

After notes equation (6), obtain following by the equations (4)

$$\begin{cases} \gamma_2 y_2 - g_2(X, y_2, y_3, \cdots, y_n) = 0 \\ \gamma_3 y_3 - g_3(X, y_2, y_3, \cdots, y_n) = 0 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ \gamma_n y_n - g_n(X, y_2, y_3, \cdots, y_n) = 0 \end{cases} \tag{8}$$

The $(n-1)$ equations were synthesized association to solve, the solutions are

$$\begin{cases} y_2 = h_2(X) \\ y_3 = h_3(X) \\ \cdots\cdots \\ y_n = h_n(X) \end{cases} \tag{9}$$

This shows that all hard mode variables $y_2, y_3, \cdots, y_n$ move together with a soft mode variable X. At this time, subsystems within the community moved together with order parameters in coordination and show the order in time, space and functions. Namely, the industrial clusters development caused by the concentration effects of self-reinforcing cycle. However, the formation process of industrial cluster's competitive advantage often accompanies with negative effect. The industrial cluster possibly moves toward withering away to the decline if it can not achieve further innovation and upgrading.

5. The Self-Organized Evolution of Industrial Cluster Upgrading to Circular Innovative Network

If we take effective measures, let the control parameter R of the system to evolve to a new critical point, and the order parameter X of the cluster leap to the new order, the cluster can be brought into a self-organized ordered structure with high efficiency and circular cluster Innovation Network. This can be introduced in synergetic method. If the notes (6) and (9) are taken into account, we also consider the random fluctuations and perturbation, from the first-available of equation (5), we know that

$$\begin{aligned} \dot{X} &= -\gamma_1 X + g_1(X, y_2, y_3, \cdots, y_n) + \Re(t) \\ &= -\gamma_1 X + g_1(X, h_2(X), h_3(X), \cdots, h_n(X)) + \Re(t) \\ &= K(X) + \Re(t) \end{aligned} \tag{10}$$

According to synergetic and nonlinear dynamics random theory, the order parameter equation (10) of cluster systemcould be regarded as a random motion equation of the nonlinear vibration damping [6,12]. $\Re(t)$ is the random-driving force, $K(X)$ is the damp-restoring force, $V(X)$ (also known as generalized potential and evolution potential) is the damp potential corresponding to $K(X)$, which satisfies

$$K(X) = -\frac{\partial}{\partial X} V(X) \tag{11}$$

Here, the order parameter evolution equation of industrial clusters turns into

$$\dot{X} = \frac{dX}{dt} = -\frac{\partial}{\partial X} V(X) + \Re(t) \tag{12}$$

Thus, the further development and changes of industrial clusters evolution will carry out under evolution potential's induction, as well as driving by random perturbation and random fluctuation force $\Re(t)$. By solving the Fokker-Planck equation similar to equation (12) (Haken, 1977)

$$\frac{dP(X)}{dt} = \dot{P(X)} = \frac{d}{dX}\left(\frac{\partial V(X)}{\partial X}P(X) + \frac{1}{2}Q\frac{dP(X)}{dX}\right) \quad (13)$$

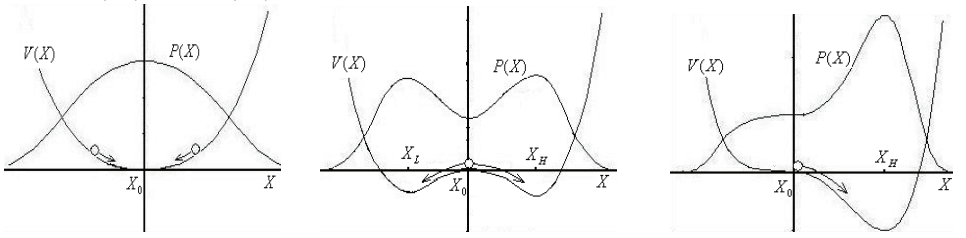
We obtain the probability distribution $P(X)$ of state variables $X(t)$:

$$P(X) = N\exp\left(-\frac{2V(X)}{Q}\right) \quad (14)$$

This shows that the state of enterprises based upon the potential function $V(X)$ are relatable. It means that the value for the probability in a point of the enterprises associated with the position of the potential function $V(X)$ .The higher of the position, the smaller of the probability. Therefore, the industry cluster will be ultimately determined by the shape and guiding the trend of potential function which makes it upgrade to a higher level or recession atrophy, or maintain the status quo. Yet the general $K(X)$ in (10) can be in Taylor expansion in the vicinity of stationary state point X_{20}, taking note of (11)after available:

$$V(X) = -\frac{1}{2}\alpha_1 X^2 - \frac{1}{3}\alpha_2 X^3 - \frac{1}{4}\alpha_3 X^4 = \beta_1 X^2 + \beta_2 X^3 + \beta_3 X^4 \quad (15)$$

In which β_1 is function of control parameter R (relating to industry field), that is, $\beta_1(R) = C(R_C - R)$. Here R_c is a critical value of control parameters R, C is a constant; parameters β_2 and β_3 are in relevance to regional niche, they are constantly positive. According to (15) and (14), we can separately spot curves of $V(X)$ and $P(X)$. As shown in Figure 1.



(a) $R < R_c$ (b) $R > R_c$ (c) after adjusting β_2 and β_3

Fig. 1 Curve of Generalized Potential $V(X)$ of Order Parameter and Its Probability Distribution $P(X)$

In which Figure (a) reflects the state of cluster system is stable, figure (b) reflects the original state lost stability. There are two possible changes , either degradation (as shown in point X_L) or upgrading (as shown in point X_H). If adjust and control the regional industrial field, and further optimize the industrial niche conditions, it can be the situation that chart(c) has shown, cluster will spontaneously migrate to another new, orderly state (self-organization emergence in complex system)[9].

6. Conclusions and Inspiration

The formation of the regional industrial cluster has generally experienced several phases including enterprise community, industry cluster, and innovation network. First, some cores of industrial agglomeration have been born out in a certain region. They can attract and induct related enterprises to gather there. Through enterprise's horizontal and vertical self-production, and self-organized division of labor based on specialization, enterprise community is gradually formed. Second, under the non-linear reaction on each other, all the subsystems come to coordinate with others, which will make the enterprise community become more orderly self-organized and highly effective, and turn into a really industrial

cluster. Third, the industrial cluster may be upgraded into circular innovation network which is a self-organized emergence of regional industrial cluster, which is an outcome of the development of industrial cluster at a more advanced stage, is also industrial cluster under the concept of circular economy. The regional circular innovation network is an environmentally-friendly development model that has more creative and competitive advantage, and vitality. In the process of implementing the regional industrial cluster, we must attach importance to the internal law of cluster's evolution, pay attention to create a favorable regional ecological condition, adjust the external field (system environment) to its position, and let the self-organized mechanism in the cluster play its role.

Though the formation and development of the circular cluster and innovation network is a self-organized and self-dependent process,[10] government function is also very important. The government should provide an effective regional environment (niche), create an industrial culture atmosphere, a creditable environment, and a system mechanism favorable for regional cluster to cooperate and innovate. Through setting the regulations on the collective acts and cooperative remuneration, and balancing the interests between the enterprises, mutual interest and benefit can be got in cooperation. Only those innovation networks created on mutual benefit and interest, they can have lasting vitality.

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