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Co-evolution mechanism of manufacturing and logistics population ecosystem driven by external environment capacity

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Abstract. The co-evolution mechanism of manufacturing and logistics is a research hotspot, but there is no good way to estimate the external stochastic disturbance factors and its nonlinear effect on environmental capacity in the existing research. To address this issue, a co-evolution population ecosystem of manufacturing and logistics is defined from the perspective of organizational ecology, and the external environmental capacity(EEC) model is established based upon logistic equation, and its stochastic influence factors are analyzed by the method of mathematical statistics. Finally, the effectiveness of the model proposed in this paper is validated through case study.

1 Introduction

The organizational ecology theory holds that the formation and evolution process of the organization is not the strategic choice and adaptation of decision makers in the organization's, but determined by the choice of external of environment. The impact of changes in the external environment on the evolution of the organization will be recorded in the number of enterprises entering or exiting the population[1], which will change the population density, environmental capacity and survival mode of the organization. So, there is a feedback in synergy mechanism between the organization and the internal and external environment. Ehrlich and Raven [2], Roughgarden [3], Jazen[4], Norgaard[5], Rosin and Belew[6] defined the interaction between Two or more species as co-evolution. Firstly, Norgaard[5]applied the concept of coevolution to the social economic fields. In "The decline of the competition", Moral[7] combined the co-evolutionary theory with the actual business cases, discussed the relationship of interdependence, interaction and co-evolution in the enterprise ecosystem. Mckelvey and Palfrey [8] studied the adaptability of the organization from the perspective of co-evolution of enterprise and environment. Lewin, Long, and Carroll [9]proposed the formation and development of evolutionary theory about the new organization. Volberda and Lewin [10] further proposed the four kinds of synergetic evolution mechanism, the nature, level, strategic choice and the overall update, which are associated. Galunic and Eisenhardt [11]considered that synergetic evolution is an important strategic means in the era of the rapid development of socialist market economy. Lenway and Murtha [12]established co-evolution model about the industry, science and technology and national system in the process of studying the printing and dyeing industry of German. Chang and Harrington[13] extended the co-evolution to the real world, and verified the co-evolution model. However, there is no good way to estimate the external stochastic disturbance factors and its nonlinear effect on EEC in the existing research.

To address this issue, firstly, this paper builds the co-evolution ecosystem of the manufacturing population(MP) and logistics population(LP), and analyses the regularity of synergetic evolution of the two; Secondly, employing the Logistic equation of Verhulst(1838), to build the co-evolution model of manufacturing and logistics; Thirdly, using the method of mathematical statistics to estimate the external stochastic disturbance factors, and put forward the method of estimating the model; Finally, according to the data of Shaanxi manufacturing and logistics, validate the validation of the model.

2 Co-evolution population ecosystem of manufacturing and logistics

The industrial activities of manufacturing and logistics can be analogous to the self-organization behavior of the bio-population in the ecosystem. In the process of evolution, various populations are constantly exchanging the material, energy and information with the external environment[9], so that the structure of the population has evolved into an orderly and stable state, which shows the self-organization regularity of the great nature. Therefore, a co-evolution population ecosystem of manufacturing and logistics is defined by analogy with the self-organization evolution process of natural ecosystem, that is, in a certain area, simulating the material circulation and energy flow of the natural ecosystem, the manufacturing enterprise and the logistics enterprise as the activity unit, forming an industrial eco-economic system which has self-organization, positive and negative feedback regulation and high efficient economic activity process between enterprise and enterprise, between enterprise and external environment, as shown in Fig. 1.

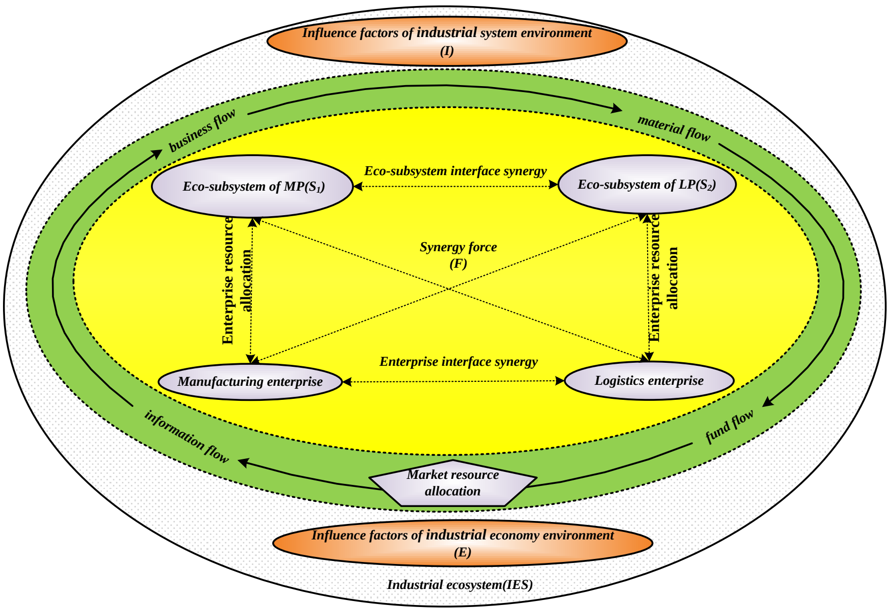

Figure 1. Co-evolution population ecosystem of manufacturing and logistics

From an ecological view, MP and LP are belong to the two subsystems of industrial ecosystem(IES), and they each have their own ecological attributes, and become an independent eco-subsystem. In the process of evolution, the eco-subsystem interface synergy between MP and LP is formed, and the enterprise interface synergy between manufacturing enterprise and logistics enterprise is formed. Furthermore, the more complex eco-behaviors that is the enterprise-level resource allocation between enterprise and eco-subsystems, and the market-level resource allocation among industrial system, economy and other influence factors in external environment. Therefore, under the joint action of enterprise resource allocation, market resource allocation and interface synergy, the co-evolution population ecosystem of manufacturing and logistics shows from disorder to orderly self-organization process, and the each eco-subsystem shows mutually synergy result.

3 Co-evolution model of manufacturing and logistics based on Logistic equation

The essence of co-evolution of manufacturing and logistics is the result of the synergy between the two mechanisms, the market-level resource allocation and the enterprise-level resource allocation. The expansion of the market and the increase of the enterprise's own resources will make the environmental capacity expand, thus forcing MP and LP to evolve in the direction of mutually beneficial symbiosis. In this study, the influence driven by the external environment changes can be simplified to two scenarios: the first is the influence of the market on the efficiency of resource allocation, which makes the change of the external stochastic disturbance factors of the environment capacity influence the changes of the industrial population scale; The second is the transfer of enterprise resource allocation within the eco-system, which makes the change of the existing industrial population scale caused by the emerging industrial population into IES. From Fig.1, It's not hard to find that the co-evolution population ecosystem of manufacturing and logistics must be influenced by the random disturbance factors in the outside system, in this, we mainly considers two points, one is by the influence of industrial system and the policy random disturbance factors, due to the guidance of the system and policy forcing the rapid development of manufacturing and logistics, which promotes the change of internal organization structure and the transformation and upgrading of industrial structure; another is by the influence of the industrial economy random disturbance factor, which is reflected in the output value of the economy. Therefore, the synergy between MP and LP is regarded as an expansion of the environmental capacity of existing population system, thus promoting the change of population growth rate. Based on the above hypothesis, the dynamics model of co-evolution population ecosystem of manufacturing and logistics driven by the external environment capacity is built by expanding the environmental capacity parameters of the Logistic equation, as follows:

$$\begin{cases} dN_1(t)/dt = r_1 N_1(t)(1 - N_1(t)/K_1(t)) \\ dN_2(t)/dt = r_2 N_2(t)(1 - N_2(t)/K_2(t)) \end{cases}, \tag{1}$$

where,

$$\begin{cases} k_1(t) = k_1^0 + \alpha_1 f_1(N_2) + \beta_1 f_1(I) + \gamma_1 f_1(E) = f_1^k(N_2, I, E) \\ k_2(t) = k_2^0 + \alpha_2 f_2(N_1) + \beta_2 f_2(I) + \gamma_2 f_2(E) = f_2^k(N_1, I, E) \end{cases}, \tag{2}$$

$N_1(t)$ and $N_2(t)$ are the population density of the manufacturing and logistics respectively; r_1 and r_2 are the natural growth rate of MP and LP, separately; $K_1(t)$ and $K_2(t)$ are the maximum environment capacity separately; $\alpha_1 f_1(N_2)$ and $\alpha_2 f_2(N_1)$ separately represent increment values of the environmental capacity of S_1 and S_2, which resulting from the synergy between MP and LP separately; I represents the industrial system environment random disturbance factor, which on the environmental capacity coefficient of influence is β_1 and β_2 respectively. E represents the industrial economic environment random disturbance factor, which on the environmental capacity coefficient of influence is γ_1 and γ_2 respectively; k_1^0 and k_2^0 respectively represent the scale of initial environmental capacity with two population system, that is $t=0$ and $f=0$, $K_1=K_1^0$, $K_2=K_2^0$.

4 Parameter estimation of the external environment capacity factors

For better parameter estimation, the Logistic equation can be simplified as follows: take any adjacent two years $[t_i, t_{i+1}]$ as the observation interval, the interval length is $\Delta t_{i+1}=t_{i+1}-t_i=1$, as shown in Fig. 2.

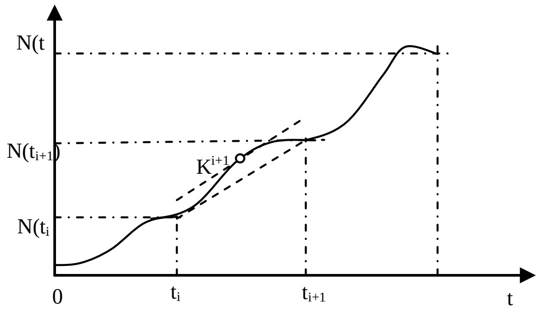

Figure 2. Population density evolution curve based on logistic equation

The increment of the population density is $\Delta N^{i+1}=N^{i+1}-N^i$ in the interval $[t_i, t_{i+1}]$, and the average value of the population density is $averN^{i+1}=\left(N^i+N^{i+1}\right)/2$, and there is $averN^{i+1}\in\left[minN(t), max\,N(t)\middle| t_i\le t\le t_{i+1}\right]$. Therefore, the slope of a line is $\Delta N^{i+1}/\Delta N^i=\Delta N^{i+1}$ on an arbitrary interval $[t_i, t_{i+1}]$, by connecting two endpoints on the curve. At this point, the slope of the curve on the interval $[t_i, t_{i+1}]$ is also the growth rate of the population density that $K(t)=K^{i+1}$ in the Logistic curve, that is:

$$\Delta N^{i+1}=rN(t)\left[1-N(t)/K^{i+1}\right]=raverN^{i+1}\left[1-averN^{i+1}/K^{i+1}\right]. \tag{3}$$

The iterative formula of the EEC can be obtained by (3), as follows:

$$K^{i+1}=\frac{raverN^{i+1}}{r-\dfrac{\Delta N^{i+1}}{averN^{i+1}}}=f^k(r). \tag{4}$$

As the $K^{i+1}>0$, there is $r-\dfrac{\Delta N^{i+1}}{averN^{i+1}}>0$, that is to satisfy $r>\dfrac{\Delta N^{i+1}}{averN^{i+1}}$ $(i=0,1,2\ldots,)$. Therefore, setting $\hat{r}$ is an arbitrary estimated value of r , a set of estimates $\hat{k}^{i+1}$ (i=0,1,2,...,n) can obtained by

(4) on the all partitions interval. Further, a set of population density estimates can be obtained by using the above estimated value $\hat{r}$ and $\hat{k}^{i+1}$, that is,

$$\hat{N}^{i+1} = \frac{\hat{k}^{i+1}}{1+\frac{\hat{k}^{i+1}-N^i}{N^i}e^{-\hat{r}}} = f^{\hat{N}}\left(\hat{r},\hat{k}\right). \tag{5}$$

For a given estimate $\hat{r}_j$, the variance of the estimated value of the population density in each observation intervals is

$$d_j = s_j^2 = \sum_{i=0}^{n}\left(N_j^{i+1}-\hat{N}_j^{i+1}\right)^2 = f_j^{s_j}\left(\hat{r}_j\right) \qquad (j=1,2) \tag{6}$$

Using the C++ program language to continuously iterate over the infinite loop estimation $\hat{r}_j$ towards the direction of variance reduction, when variance d_j can no longer reduce or less than the set threshold, the corresponding estimate $\hat{r}_j$ is the natural growth rate r of the population. Then, the estimated value $\hat{k}_j$ and $\hat{N}_j$ can be obtained by (4) and (5).

5 Analysis of examples

This study chooses Shaanxi Province as the research object to estimate the environment capacity of co-evolution population ecosystem of manufacturing and logistics. Data originates from the "China Statistic Yearbook"[20], "Shaanxi Statistic Yearbook"[22], and "China Tertiary Industry Statistic Yearbook"[23]. According to above methods, the natural growth rate of manufacturing and logistics is $r_1 = 0.2412$ and $r_2 = 0.1474$ respectively, and the estimated value of k_j and N_j as shown in Fig.3.

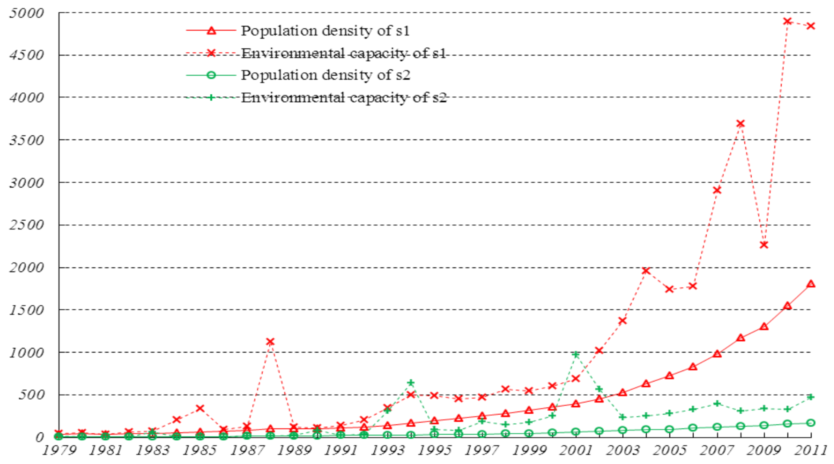

Figure 3. The relationship between population density and EEC

The Fig.3 clearly showing the trend of changes in the EEC and the population with the time, it can be seen that Shaanxi manufacturing and logistics in the current development space is very large, which at the growing stage of the logistics curve, but the growth rate is different. To obtain the detailed parameters of EEC model, the coefficients of the equations are caculated by mathematical statistical analysis, that is, with the test of the model F is significant, the R^2 is high, and the variable coefficient t is significant as the principle, to gradually progressive regression and tentative regression, and finally get the $N_j(t), j=1,2$ and $K_j(t), j=1,2$, as following:

$$\begin{cases} K_1(t)=25.531-10.877N_2(t)+1.534(N_2(t))^2-2.455(I(t))^2+1.089(I(t))^3 \\ K_2(t)=-47.844-0.786(N_1(t))^2+12.487E(t) \end{cases}. \tag{7}$$

where $t=0,1,2\Lambda,T$, $R^2 \geq 0.780$ ($F \geq 47.091$), which illustrated that the fitting effect of the equations on the sample points is good. The sig.<0.01, which shows that the regression equation is well. To further discuss the growth rate of $K_1(t)$ and $K_2(t)$, the first derivative of (7) with respect to t, as following:

$$\begin{cases} f'(K_1)=\frac{dk_1}{dt}=\frac{dN_2}{dt}+\frac{dI}{dt}=-10.877+3.068N_2(t)-4.910I(t)+3.267(I(t))^2 \\ f'(K_2)=\frac{dK_2}{dt}=\frac{dN_1}{dt}+\frac{dE}{dt}=-1.572N_1(t)+12.487 \end{cases}. \tag{8}$$

The varying rate of EEC varies between manufacturing and logistics, as following: the change rate of EEC of manufacturing is quadratic function, in which, the synergy performance is positive effect(3.068) from logistics, and the industrial system environment performance is shown as short-term positive effect, there is a maximum value. However, the change rate of EEC of logistics is characterized by linear function, and synergy performance is negative effect(-1.572), and the performance of industrial system environment and the synergy of manufacturing are not obvious.

6 Conclusions

The regularity of co-evolution of manufacturing and logistics originates from the refinement of social division of labor and the integration of industry. The logistics separates from the manufacturing embodies the process of co-evolution of internal manufacturing system. The logistics is independent from the manufacturing as a new industry system, which embodies the co-evolution process between industries. The essence of these two kinds of co-evolution is the interaction mechanism between enterprise-level and market-level on allocation of resources. In the process of evolution, the formation of dynamic feedback mechanism between the organizational population and the outside environment, the system internal synergy forces, the external environment random stochastic disturbance factors, make the system from disorderly to orderly self-organization ecological process.

Owing to the dual role between policy system delays and the economic development needs, result in different environmental capacity of the co-evolution for manufacturing and the logistics, which shows that the strength of industrial activity is closely related to policy system and economic environment, and can have a significant impact on industrial environment capacity evolution on important policy nodes. The research expands the relationship between manufacturing and logistics, and provides a reference for research on the mechanism of synergy between industrial systems, and on the relationship between industrial evolution and environmental impacts.

Acknowledgment

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References

[1] P. A. Geroski and M. Mazzucato, “Modelling the dynamics of industry populations,’’ International Journal of Industrial Organization, vol. 19, pp. 1003-1022, 2001.

[2] P. R. Ehrlich and P. H. Raven, “Butterflies and Plants: A Study in Coevolution,” Evolution, vol. 18, pp. 586-608, 1964.

[3] J. Roughgarden, “Resource partitioning among competing species--a coevolutionary approach,” Theoretical Population Biology, vol. 9, pp. 388-424, 1976.

[4] D. H. Janzen, “When is it Coevolution?,” Evolution, vol. 34, pp. 611-612, 1980.

[5] R. B. Norgaard, “Coevolutionary Agricultural Development,” Economic Development and Cultural Change, vol. 32, pp. 525-546, 1984.

[6] C. D. Rosin and R. K. Belew, “New methods for competitive coevolution,” Evolutionary Computation, vol. 5, p. 1, 1997.

[7] R. D. Moral, “On the variability of chlorogenic acid concentration,” Oecologia, vol. 9, pp. 289-300, 1972.

[8] R. D. Mckelvey and T. R. Palfrey, “Quantal Response Equilibria in Normal Form Games,” Games & Economic Behavior, vol. 10, pp. 6-38, 1995.

[9] A. Y. Lewin, C. P. Long, and T. N. Carroll, “The Coevolution of New Organizational Forms,” Organization Science, vol. 10, pp. 535-550, 1999.

[10] H. W. Volberda and A. Y. Lewin, “Co−evolutionary Dynamics Within and Between Firms: From Evolution to Co−evolution,” Journal of Management Studies, vol. 40, pp. 2111–2136, 2003.

[11] D. C. Galunic and K. M. Eisenhardt, “Architectural Innovation and Modular Corporate Forms,” Academy of Management Journal, vol. 44, pp. 1229-1249, 2001.

[12] S. A. Lenway and T. P. Murtha, “Knowledge and competitive advantage, the coevolution of firms, technology and national institutions,” Journal of International Business Studies, vol. 72, pp. 727–729, 2004.

[13] M. H. Chang and J. Harrington, “Agent-Based Models of Organizations,” 2004, pp. 1273-1337.

[14] P. F. Verhulst, “Notice sur la loi que la population suit dans son accroissement. Correspondance Mathematique et Physique Publiee par A Quetelet, Brussels,” Quetelet, vol. 10, pp. 113-121.

[15] T. R. Malthus, “essay on the principle of population,” Harmondsworth England Penguin, vol. 41, pp. 114-115, 1959.

[16] R. M. May, “Simple mathematical models with very complicated dynamics,” Nature, vol. 261, pp. 459-67, 1976.

[17] Y. Takeuchi, Global Dynamical Properties of Lotka-Volterra Systems: WORLD SCIENTIFIC, 1996.

[18] M. T. Hannan and J. Freeman, "The Population Ecology of Organizations," American Journal of Sociology, vol. 82, pp. 929-964, 1977.

[19] X. Yang and Y. K. Ng, "Specialization and economic organization : a new classical microeconomic framework," Contributions to Economic Analysis, 1993.

[20] National Bureau of Statistics of the People's Republic of China, China Statistical Yearbook: Beijing: China Statistics Press, 1981-2016.

[21] Shanxi Provincial Bureau of Statistics, "Shanxi Statisical Yearbook," 1986~2012.

[22] National Bureau of Statistics of the People's Republic of China, 2012 China Statistical Yearbook of the Tertiary Industry: Beijing: China Statistics Press, 2012.