Industrial Cluster Evolution Based on SOM Neural Network

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Abstract
By connecting path dependence theory and industrial cluster evolution with relevant corporate indexes, this paper conducts an in-depth analysis of the influence of corporate indexes on industrial cluster evolution, and finally puts forth an industrial cluster evolution model based on SOM neural network model. Analysis results of the industrial clusters of Heilong's pharmaceutical industry suggest that SOM network model based on corporate indexes and path dependence theory can qualitatively and quantitatively analyze the evolution process of industrial clusters.
Key words: INDUSTRIAL CLUSTERS; PATH DEPENDENCE; SOM INDEX MODULE.

1. Introduction

Industrial cluster refers to an economic phenomenon that a large number of relevant enterprises of the same type gather in a specific area [1]. Enterprises can obtain huge competitiveness through clusters so as to obtain better development and rich economic benefits [2]. As an effective organization model, regional industrial cluster has drawn more and more attention from the academic field and the government's decision-making departments.

Research into industrial cluster can be traced back to the late 19th century. Since that time, famous Western economics like Marshall [3] have studied the cluster development phenomenon of enterprises. Marshall put forward the connotation and extension of industrial cluster, and discussed the basic causes of industrial cluster. He thought that, "Local industries continuously improve their techniques so as to meet market requirements and maximize profits. Employers often go to regions where there are workers with professional skills. On the other hand, job-seekers will also go to areas where their skills are wanted." Later, Weber et al. [4] put forth the minimum cost principle deciding the industrial location, revealing the basic motivation for the formation of industrial location lies in the attraction of economic benefits and cost conservation to the industry. However, Joseph Schumpeter [5] mainly explained the industrial cluster phenomenon from the innovation perspective, thinking that industrial cluster contributes to innovation, and vice versa. Innovation is not an individual behavior of enterprises. It calls for mutual cooperation and cooperation between enterprises, and is realized through cluster of enterprises.

Currently, research into industrial cluster has been diversified both at home and abroad. LI Wei, CHEN Jun, et al. [6] studied the development path and the industrial cluster effect of the regional new-and high-tech industry; Atienza, Arias, et al. [7] conducted an in-depth analysis of large-scale mining enterprises and regional development and cluster, and provided an ideal cluster evolution process for mining enterprises. However, at present, research into the generation process and evolution rules of industrial cluster still stays in the qualitative discussion period, which lacks research depth and cannot quantitatively describe the industrial cluster results [8-9].

Therefore, this paper introduces the Path Dependence Theory. The state-depending Path Dependence refers to that a self-strengthening phenomenon will appear in response to the appearance of certain technique or system, and make the environment suitable for its survival and not suitable for the survival for other techniques or systems. The behavior-depending Path Dependence refers to that the market will reward and punish different behavioral agents under the same initial conditions and opportunities, and that the rewarded will work harder to improve their ability and form a virtuous circle [10]. Based on the above analysis of Path Dependence Theory, this paper connects Path Reliance Theory and industrial cluster evolution, puts forward the industrial cluster evolution mechanism based on the SOM neural network model analysis, and applies the mechanism to Heilongjiang provincial pharmaceutical industrial clusters. Comprehensive results of various corporate model indexes are first analyzed. At last, the SOM network already built up is trained through various index module, and various index modules are analyzed to provide a new analysis method for the cluster evolution direction of various enterprises and the academic research of industrial cluster.

2. Industrial cluster evolution based on the SOM neural network model

2.1. SOM neural network structure

The competition-type neural network is a kind of self-organizing competitive neural networks, which is also called SOM neural network [11-12]. The network adopts non-guidance learning, namely no need for providing corresponding output, and the network just relies on characteristics of the input model to modify the weight of unit connection according to certain judgment criterion and through continuous training, and make the distribution of the weight vectors in the input vector space similar to that of samples. The basic competition-type neural network is made up of the input layer and the output layer. (See Fig. 1) Assume that there are “N” nerve cells in the input layer and “M” nerve cells in the competition layer; the network connection weight value is w_{ij}, where $(i=1,2,\cdots,N;\ j=1,2,\cdots,M)$, and it meets the constraint condition of $\sum_{i=1}^{N} w_{ij}=1$. In the competition layer, nerve cells compete with each other. At last, only one or several neural cells succeed and get adapted to the current input samples. The neural cell/cells succeeding in the competition stands/stand for the classification model of the input samples.

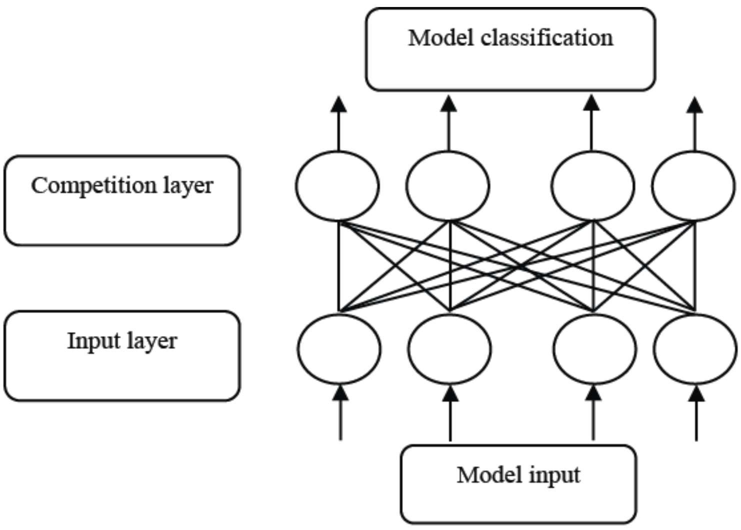


Figure. 1 SOM neural network model structure

2.2. SOM neural network algorithm flow

The following are the algorithm flow steps of the competition-type model:

Step 1: Set w_{ij} to be a random value within [0,1] according to the restriction conditions;

Step 2: Randomly choose Model “X” from “T” learning models for the network output layer, and calculate the input value, S_j ,of various nerve cells in the competition layer according to the following equation:

$$S_j = \sum_{i=1}^{N} w_{ij} X_i \quad (1)$$

Where, $i = 1, 2, \cdots, N$. X_i stands for the “i” element of the vector of the input sample.

Step 3: Adopt the nerve cell corresponding to the maximum in S_j ($j = 1, 2, \cdots, M$). Set the output state to be “1” and the output state of the other nerve cells to be “0.” According to the competition mechanism, the neural network, *k*, with the maximum weight value will succeed. The a_k is output as is shown in Eq. (2):

$$a_k = \begin{cases} 1, & s_k > s_j, \forall j, k \neq j \\ 0, & \text{Other} \end{cases} \quad (2)$$

Step 4: Amend the connection weight value of the succeeding nerve cells, while maintain that of the other nerve cells unchanged. The weight value is shown in Eq. 3 below:

$$w_{ij} = w_{ij} + a(\frac{X_i}{m} - w_{ij}) \quad (3)$$

Where, $i = 1, 2, \cdots, N$. a stands for the learning parameter, and 0<a<1. Generally speaking, it ranges within 0.01~0.03, m stands for the number of nerve cells in the input layer with the output value of “1.” Step 5: Choose another learning mode, and return to Step 3 until there are “T” learning models for the network. Return to Step 2 until the adjustment value of various connection weights is quite small.

2.3. Construction steps of industrial cluster evolution based on SOM

Based on the above discussion of structural characteristics of SOM neural network and its algorithm flow, it can be seen that the structure and algorithm flow of the model shares a high resemblance with the Path Dependence Theory. According to the state-dependent Path Dependence Theory, when a technique or system of an enterprise appears and is implemented, adaptability of the enterprise to market environment will be strengthened. In other words, through self-transformation, the enterprise is further improved in terms of certain index to form an ecological field suitable for its survival, and to fundamentally change its property.

In terms of SOM neural network model, it analyzes the value of all indexes of a sample to work out the input value, S_j, of various nerve cells in the competition layer, and adopt the nerve cell corresponding to the maximum value of S_j to judge the value of the output index category of the sample. Thus, SOM neural network model adopts the current sample and its various indexes for SOM network model training and builds a discrimination system targeted at the property category of the sample. Based on the system, the variation of the value of the output indexes of the sample is simulated when the sample indexes change. After that, the industrial cluster evolution rules based on Path Dependence Theory is simulated.

Through the above analysis of the SOM model and the industrial cluster based on the Path Dependence Theory, this paper puts forward the following steps to build the SOM neural network industrial cluster evolution model based on the Path Dependence Theory.

Step 1: Conduct maximin normalization of all indexes of the sample, and work out the weight value of various model indexes through the Analytic Hierarchy Process; conduct weighting of the value of various model indexes and obtain the comprehensive results of various model indexes;

Step 2: Adopt the comprehensive index value of the sample and various modules as the input information of SOM network; assume the category index number of the model is “4,” train the established SOM network, and adopt the model weight value as the center of industrial clusters of different categories.

Step 3: Analyze the influence of various indexes on the target category value according to the Path Dependence Theory and based on the industrial cluster centers of various sample categories, and provide the evolution rules of centers of various categories. At last, the variation of the output value when indexes of different samples change is analyzed according to the Path Dependence Theory.

3. Model establishment and result analysis

3.1. Comprehensive calculation results of various model indexes of the sample

This paper adopts Heilongjiang provincial pharmaceutical industry as an example. The data investigation and acquisition method is targeted at various enterprises. 100 copies of questionnaires are sent to employees within the industry. At last, the mode of various indexes in the questionnaire survey is adopted as the final value of indexes. “0” stands for “strong opposition;” “1” stands for “opposition;” “2” stands for “no agreement and opposition;” “3” stands for “agreement of considerable degree;” “4” stands for “agreement;” “5” stands for “strong agreement.” Information of various indexes in the questionnaire survey targeted at various enterprises is shown in Table 1:

Table 1. Core indexes of the questionnaire survey

Item	Model	Model index
A	The most important factors influencing the development of new products in enterprises	A1: More and more customers in the industry have started using the product. (Increase of demands) A2: More and more enterprises in the industry have started developing (supplying) similar products. (Increase of supply) A3: More and more customers in the industry have started using complementary products. (Increase of demands of complementary products) A4: More and more enterprises in the industry have developing complementary products. (Increase of supply of complementary products)
B	The most important factors influencing the introduction of new techniques in enterprises	B1: More and more customers have raised special requirements of the technique. (Customer requirements) B2: More and more counterparts have started using the production technique. (Use of counterparts) B3: The technique helps an enterprise decrease production cost and improve production procedures. (Cost reduction) B4: The production technique is improved according to the industrial standards and the requirements of quality certification system. (Quality standard)
C	The most important strategic goals in the recent three to five years	C1: Maintain the current market share. C2: Develop new techniques and obtain technical advantages. C3: Develop new products and new markets. C4: Expand production, such as building new plants, purchasing new devices, etc.
D	Debt-paying ability	D1: Average growth rate of the sales revenue.

The author conducts a questionnaire survey of 19 pharmaceutical enterprises in Heilongjiang Province, and the data index value of the sample is shown in Table 2 below.

Table 2. Value of various indexes of the 19 pharmaceutical enterprises

Enterprise name	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1
1	5	4	3	2	2	3	5	5	2	5	4	5	0.50
2	5	5	5	5	4	0	0	5	5	5	5	5	0.4
3	3	3	2	1	0	0	4	2	4	4	5	3	-0.18
4	2	1	2	2	2	2	2	2	5	5	4	4	0.12
5	3	3	3	3	3	3	4	3	5	5	5	5	0.15
6	3	5	3	3	5	5	5	4	4	4	3	4	0.12
7	5	1	2	2	2	2	3	5	2	4	4	5	0.32
8	2	3	2	2	3	3	4	4	0	5	5	3	0.31
9	1	2	1	1	4	3	3	4	1	2	3	2	0.14
10	1	2	2	1	1	2	2	2	4	3	3	4	0.33
11	3	3	2	2	5	3	4	4	5	5	5	5	0.16
12	3	3	4	3	1	3	4	5	4	5	5	4	0.38
13	1	1	1	1	2	2	3	5	0	5	5	5	0.29
14	4	3	3	5	5	4	4	5	4	3	5	5	0.79
15	5	5	5	5	5	5	5	5	5	5	5	5	0.75
16	3	5	3	3	4	5	3	3	5	5	5	5	0.20
17	2	1	4	3	3	3	3	4	0	4	4	4	0.10
18	2	2	3	3	2	2	2	3	3	3	5	3	0.69
19	5	0	0	0	5	0	5	5	5	5	5	5	0.54

A high index value means that the enterprise has not been recognized by employees for certain system or technique. In other words, the enterprise has not yet been improved in terms of the index. Thus, the smaller the value of the former 12 indexes, the better. However, to the average growth rate of sales income, the larger the value of the index, the better. Therefore, various indexes in the above undergo maximin normalization. The normalization numerical value obtained is shown in Table 3 below:

Table 3. Normalization of various indexes of the 19 pharmaceutical enterprises

Enterprise name	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1
1	0.00	0.20	0.40	0.60	0.60	0.40	0.00	0.00	0.60	0.00	0.50	0.00	0.68
2	0.00	0.00	0.00	0.00	0.20	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.67
3	0.50	0.40	0.60	0.80	1.00	1.00	0.20	1.00	0.20	0.33	0.00	0.67	0.01
4	0.75	0.80	0.60	0.60	0.60	0.60	0.60	1.00	0.00	0.00	0.50	0.33	0.30
5	0.50	0.40	0.40	0.40	0.40	0.40	0.20	0.67	0.00	0.00	0.00	0.00	0.33
6	0.50	0.00	0.40	0.40	0.00	0.00	0.00	0.33	0.20	0.33	1.00	0.33	0.31
7	0.00	0.80	0.60	0.60	0.60	0.60	0.40	0.00	0.60	0.33	0.50	0.00	0.51
8	0.75	0.40	0.60	0.60	0.40	0.40	0.20	0.33	1.00	0.00	0.00	0.67	0.50
9	1.00	0.60	0.80	0.80	0.20	0.40	0.40	0.33	0.80	1.00	1.00	1.00	0.33
10	1.00	0.60	0.60	0.80	0.80	0.60	0.60	1.00	0.20	0.67	1.00	0.33	0.51
11	0.50	0.40	0.60	0.60	0.00	0.40	0.20	0.33	0.00	0.00	0.00	0.00	0.34
12	0.50	0.40	0.20	0.40	0.80	0.40	0.20	0.00	0.20	0.00	0.00	0.33	0.56
13	1.00	0.80	0.80	0.80	0.60	0.60	0.40	0.00	1.00	0.00	0.00	0.00	0.47
14	0.25	0.40	0.40	0.00	0.00	0.20	0.20	0.00	0.20	0.67	0.00	0.00	0.98
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93
16	0.50	0.00	0.40	0.40	0.20	0.00	0.40	0.67	0.00	0.00	0.00	0.00	0.39
17	0.75	0.80	0.20	0.40	0.40	0.40	0.40	0.33	1.00	0.33	0.50	0.33	0.29
18	0.75	0.60	0.40	0.40	0.60	0.60	0.60	0.67	0.40	0.67	0.00	0.67	0.88
19	0.00	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73

The pairwise comparison matrix of the weight value of various model indexes in this paper is shown in Eq. (4) below:

$$B=\begin{bmatrix}1 & 2 & 1/2 & 1/3\\ 1/2 & 1 & 1/4 & 1/5\\ 2 & 4 & 1 & 2\\ 3 & 5 & 1/2 & 1\end{bmatrix},\quad B=\begin{bmatrix}1 & 2 & 1/2 & 1/3\\ 1/2 & 1 & 1/4 & 1/5\\ 2 & 4 & 1 & 2\\ 3 & 5 & 1/2 & 1\end{bmatrix},\quad C=\begin{bmatrix}1 & 1/5 & 1/3 & 1/3\\ 5 & 1 & 3 & 4\\ 3 & 1/3 & 1 & 2\\ 3 & 1/4 & 1/2 & 1\end{bmatrix} \qquad (4)$$

By solving the above pairwise comparison matrixes, the maximum eigenvalue and the corresponding eigenvector are obtained, and a consistency check is conducted of them. The weight value of various indexes is shown in Table 4 below:

Table 4. Weight value of various model indexes

A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1
0.47	0.28	0.17	0.08	0.16	0.08	0.42	0.34	0.08	0.54	0.23	0.15	1.0

Based on weighting summation of the normalized value of indexes of various pharmaceutical enterprises in Heilongjiang Province, the comprehensive results of various model indexes of various enterprises are shown in Table 5 below:

Table 5. Comprehensive index results of the industrial cluster of various enterprises

Enterprise name	1	2	3	4	5	6	7	8	9	10
A	0.172	0.000	0.512	0.727	0.447	0.334	0.375	0.614	0.837	0.803
B	0.125	0.532	0.663	0.738	0.407	0.115	0.310	0.293	0.346	0.769
C	0.160	0.000	0.298	0.166	0.000	0.476	0.341	0.178	0.985	0.657
D	0.68	0.67	0.01	0.30	0.33	0.31	0.51	0.50	0.33	0.51
Enterprise name	11	12	13	14	15	16	17	18	19	
A	0.496	0.413	0.894	0.298	0.000	0.334	0.643	0.621	0.531	
B	0.231	0.240	0.310	0.100	0.000	0.429	0.377	0.623	0.080	
C	0.000	0.066	0.076	0.376	0.000	0.000	0.422	0.493	0.000	
D	0.34	0.56	0.47	0.98	0.93	0.39	0.29	0.88	0.73	

3.2. Construction and training of SOM network

Adopt the financial index data of various chosen samples as the input of the SOM network. The structural schematic diagram of the competition-type neural network is shown in Fig. 2.

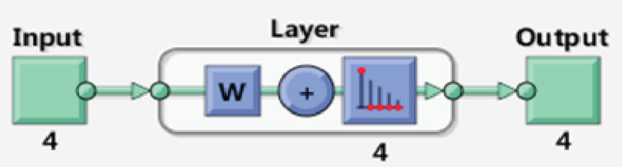


Figure. 2 Schematic diagram of the SOM neural network model

Relevant parameters of the network during training are shown in Table 6. Trainru (non-supervision and random) function is adopted to conduct training of the network. The initial learning rate and the learning rate after adjustment are both 0.3. The maximum iterations are 150.

Through the operation of the model, the weight value of the comprehensive indexes of industrial clusters of various categories, and the category distribution of sample enterprises are shown in Table 7 and Fig. 3, respectively:

Table 6. Relevant parameters for SOM neural network training

Layout function	Hextop Function (hexagonal topological function)	Learning rate during the adjustment period	0.3
Distance function	Linkdist Function (Link distance weight function)	Adjacent distance during the adjustment period	10-6
Learning rate during the ranking period	0.3	Network iterations	150
Step length during the ranking period	300	Network training function	Trainru function

Table 7. Weight value of comprehensive indexes of industrial clusters of various types

Index	Category 1	Category 2	Category 3	Category 4
A	0.1176	0.4432	0.5323	0.7047
B	0.1893	0.349	0.2843	0.5786
C	0.1341	0.4367	0.0459	0.5054
D	0.8157	0.5635	0.4744	0.2881

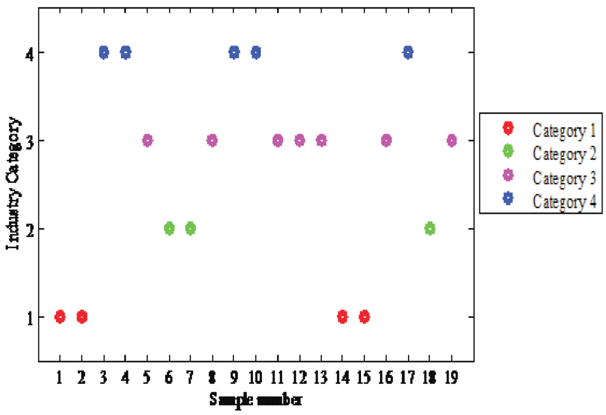
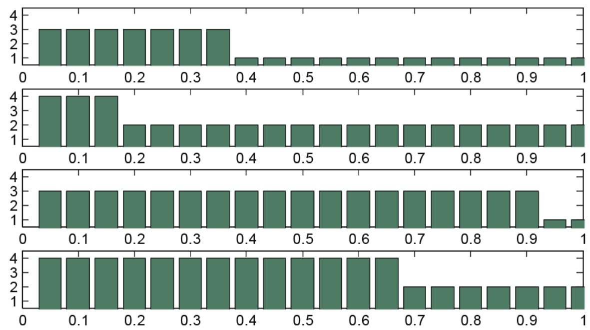


Figure. 3 Distribution of categories of various enterprise samples

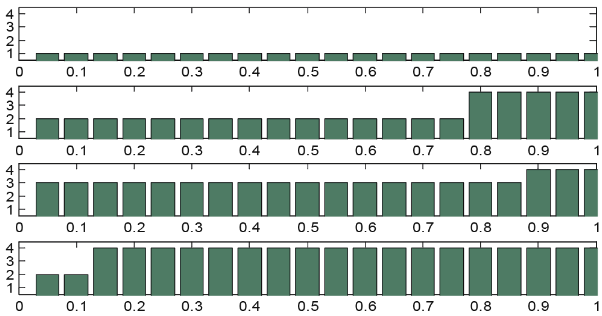
The above simulation of various category centers shows that the economic benefits of enterprises of Category 1 are better, but are poor in terms of A, B and C index modules. In other words, the index of Model A, B and C is not complete. In terms of enterprises of Category 2, the value of all index modules is relatively even, but is all at a medium and relatively low level. In terms of enterprises of Category 3, A, B and C index modules differ not greatly from those of Category 2, but is relatively low in terms of the index of Model c. In terms of Category 4, enterprises are relatively high in terms of all model indexes except the index of Model D. From the distribution of the weight value above, it can be seen that enterprises of various categories have their own characteristics and defects.

3.3. Analysis of industrial cluster evolution

In order to dig the influence of various index modules on industrial cluster evolution, this paper conducts a sensitivity analysis of various index modules according to the Path Dependence Theory, and conducts simulation based on the above well-trained SOM network model. The distribution of the influence of various index modules on industrial cluster evolution of various categories is shown in Fig. 4 below:



(a)



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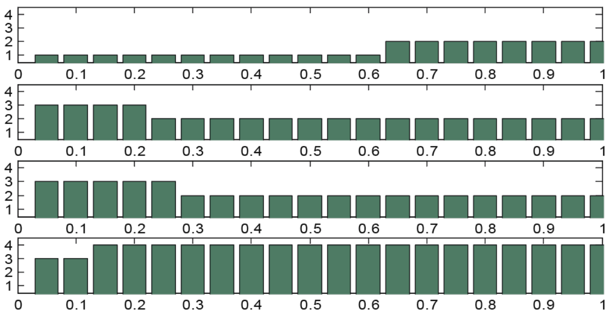
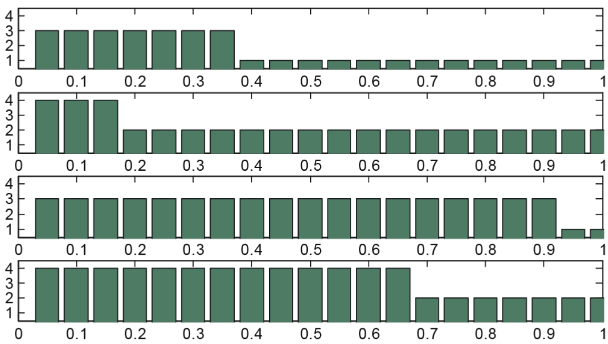


(c)



(d)

Figure. 4 Influence of variation of various index modules on industrial cluster evolution. Figure. a, b, c and d show the influence of Index Module A, B, C and D on industrial cluster of various categories.

Based on the above charts showing the influence of various index modules on evolution of industrial clusters of various categories, it can be seen that:

In terms of Index Module A, it can be seen from Fig. a: When Index Module A is smaller than 0.35, enterprises of Category 1 will evolve to enterprises of Category 3. When Index Module A is smaller than 0.15, enterprises of Category 1 will evolve into enterprises of Category 3. When Index Module A is larger than 0.9, enterprises of Category A will evolve into enterprises of Category 4. As to enterprises of Category 3, when Index Module is smaller than 0.9, enterprises will evolve into enterprises of Category 1. In terms of enterprises of Category 4, when Index Module 4 is larger than 0.65, enterprises will evolve into enterprises of Category 2.

In terms of Index Module A, it can be seen from Fig. b: The index module has no influence on enterprises of Category 1. In terms of enterprises of Category 2, when the value of Index Module B is larger than 0.75, enterprises will evolve into enterprises of Category 4. In terms of enterprises of Category 3, when Index Module B is larger than 0.85, enterprises will evolve into enterprises of Category 4. In terms of enterprises of Category 4, when Index Module B is smaller than 0.15, enterprises will evolve into enterprises of Category 2.

In terms of Index Module C, it can be seen from Fig. c: In terms of enterprises of Category 1, when Index Module C is larger than 0.6, enterprises will evolve into enterprises of Category 2. In terms of enterprises of Category 2, when Index Module C is smaller than 0.25, enterprises will evolve into enterprises of Category 3. In terms of enterprises of Category 3, when Index Module C is larger than is larger than 0.25, enterprises will evolve into enterprises of Category 2. In terms of enterprises of Category 4, when Index Module C is smaller than 0.15, enterprises will evolve into enterprises of Category 3.

In terms of Index Module D, it can be seen from Fig. d: In terms of enterprises of Category 1, when Index Module D is smaller than 0.4, enterprises will evolve into enterprises of Category 3. In terms of enterprises of Category 2, when Index Module D is smaller than 0.2, enterprises will evolve into enterprises of Category 4. In terms of enterprises of Category 3, when Index Module D is larger than 0.9, enterprises will evolve into enterprises of Category 1. In terms of enterprises of Category 4, when Index Module D is larger than 0.65, enterprises will evolve into enterprises of Category 2.

All the above evolution results of enterprises of the various categories are shown in Table 8 below:

Table 8. Influence of various index modules on evolution of industrial clusters of various categories

Index Module	Category 1	Category 2	Category 3	Category 4
A	<0.35,1→3	<0.15,2→4	>0.9,3→1	>0.65,4→2
B	None influence	>0.75,2→4	>0.85,3→4	<0.15,4→2
C	>0.6,1→2	<0.25,2→3	>0.25,3→2	<0.15,4→3
D	<0.4,1→3	<0.2,2→4	>0.9,3→1	>0.65,4→2

4. Conclusions

This paper mainly studies the industrial cluster evolution based on the SOM neural network model. Based on the Path Dependence Theory, industrial cluster evolution is connected with the index value of samples. After that, industrial cluster evolution based on the SOM network model and the Path Dependence Theory is put forward. Based on various industrial cluster categories, the influence of various index modules on industrial cluster evolution of enterprises of various categories is analyzed. Results suggest: Apart from Index Module B which has none influence on the cluster evolution of Category 1, all the variation of all the other index modules can lead to corresponding changes of enterprises' industrial cluster evolution. Among them, Category 1 evolves into Category 2 and Category 3 as a whole; Category 2 evolves into Category 3 and Category 4 as a whole; Category 3 evolves into Category 1, Category 2 and Category 4 as a whole; Category 4 evolves into Category 2 and Category 3 as a whole.

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