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Capacity Evaluation Model of Enterprise Technological Innovation Complex System and Its Application

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Abstract

Under the background of complex system of enterprise innovation, based on the self-organization theory and collaborative theory, it is thought that the enterprise technology innovation system belongs to the grey system, for this reason, build the grey relational analysis model of the enterprise technology innovation system capability evaluation, and use weight coefficient method to optimize. Finally, use the optimization model to evaluate the technological innovative ability of seven enterprises; the results show that the built enterprise technology innovation system ability evaluation model is effective, and it can offer the innovation ability value of different enterprises accurately, providing the useful decision-making reference for the enterprise technology innovation system and the optimization of technological innovation cooperative system.

Keywords*: Complex System, Technological Innovative Ability, System Evaluation, Grey Relational Degree, Weight Coefficient Method*

1. Introduction

Due to the era development, the competitive environment, new customer demand, enterprise technology innovation theory, increasing practical difficulties and the complex innovation process, the enterprise technology innovation system must adapt to the change of the complex system, adapt to the systematic perspective, dynamic perspective and cooperative perspective of market; under this background, how to evaluate the enterprise technological innovation capability of the enterprise itself and the different enterprises (that is, the technological innovation ability ranking) is worth studying.

According to the description of the self-organizing theory, enterprise technology innovation system originates from the non-equilibrium (in the sense of innovation, the equilibrium is relatively balanced, so there is dynamic condition), so it needs to inspire the relatively stable structure to change, and realize the new non-equilibrium steady state. But it is hard for the self-organization process analysis based on the internal non-equilibrium process to guide the enterprise to build executable management architecture. For non-equilibrium transformation process, therefore, the change factor must be found from the external equilibrium (often expressed by external control variables), so that the complexity and difficulty of implementing and the building the model can be lowered. At the same time, the characteristics of self-organization are reflected in the collaborative theory, which can be used to analyze and describe the nonlinear dynamic economic system [1], in particular, it can be used to analyze and describe the complex system consisting of the subsystems with entirely different characteristics [2]. A variety of highly nonlinear phenomena are considered to assess the capabilities and the generalization extent of the suggested approach [3]. So the "collaborative" can be defined as: different subsystems, through cooperation and competition, form the space-time or function

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architecture in the macroscopic level [4]. In other words, collaboration defines the self-organizing rules of the subsystem from the overall level rather than exploring the specific properties of subsystems. Peng Jisheng, on the basis of market competition structure change, discusses the evolution rule of technological innovation, thinks that the technology innovation has generated five generations of innovation process models, and the change tendency is the technology collaborative innovation model [5].

To sum up, Michela Milano and Michele Lombardi address problems where decisions to be taken affect and are affected by complex systems, which exhibit phenomena emerging from a collection of interacting objects, capable to self-organize and to adapt their behaviour according to their history and feedback [6]. the project team thinks that the enterprise technology innovation complex system involves the cooperative game of collaborative system [7-9], not only including the enterprise product development system and production system, but also including the corporate strategic decision-making, marketing and human resources such, the essence of which is an incomplete, imprecise grey system; the grey relational analysis can be selected evaluating the technological innovation capability of enterprise itself and different enterprises, that is, on the basis of the evaluation index of system evaluation object, use the correlation analysis of grey system theory to calculate the relevancy of the evaluation object, and rank the evaluation objects according to the correlation [10]. Designing the way a complex system should evolve to better match customers' requirements provides an interesting class of applications [11], the team optimizes the grey relational analysis model, uses weight coefficient method to determine the weight of each evaluation index, in order to reduce the human factor, improve the scientific nature and rationality of the evaluation model [12].

2. Building the Grey Relational Analysis Model of Enterprise Technology Innovation Capability Evaluation

Model assumption:

(1) Given that there are "m" enterprises to be evaluated, and there are "n" evaluation indexes, all indicators are expressed with vector, written as $X_i = (x_{i1}, x_{i2} \dots, x_{in}),\ i = 1,2,\cdots,m$.

(2) Given that $x_{0j}\ (j = 1,2,\cdots,n)$ is the optimal value of the" j " indicator in the enterprises to be evaluated; when the indicator is the "efficiency" indicator, x_{0j} is the maximum value; when the indicator is the "cost" indicator, x_{0j} is the minimum value. So $X_0 = (x_{01}, x_{02}, \cdots, x_{0n})$ can be seen as the optimal enterprise evaluation system as the reference standard for evaluation.

The standard processing formula of original index value is:

$$y_{ij} = \frac{x_{ij} - \min\limits_i(x_{ij})}{\max\limits_i(x_{ij}) - \min\limits_i(x_{ij})}, \tag{1}$$

$$y_{ij} = \frac{\max\limits_i(x_{ij}) - x_{ij}}{\max\limits_i(x_{ij}) - \min\limits_i(x_{ij})}. \tag{2}$$

After the standard indicator, the correlation coefficient ε_{ij} can be obtained:

$$\varepsilon_{ij} = \frac{\min_i \min_j \left| y_{0j} - y_{ij} \right| + \rho \max_i \max_j \left| y_{oj} - y_{ij} \right|}{\left| y_{0j} - y_{ij} \right| + \rho \max_i \max_j \lfloor y_{0j} - y_{ij} \rfloor}, (i = 1,2,\cdots,m,\ j = 1,2,\cdots,n). \tag{3}$$

Thus the correlation w_i of various enterprises and the optimal enterprises:

$$w_i = \sum_{j=1}^{n} u_j \varepsilon_{ij}. \tag{4}$$

The formula explains that: formula (1) specification against the "efficiency" indicator; formula (2) specification against the "cost" indicator; in formula (3), ε_{ij} is the "j" correlation coefficient of the "i" optimal enterprise, "ρ" is the resolution coefficient, $\rho \in [0,1]$, generally ρ is 0.5; in formula (4), w_i reflects the comprehensive correlation of all the indicators, which is the correlation of each enterprise and the optimal enterprise, u_j is the weight of evaluation index. According to the formula (4), the size of w_i can determine the enterprise technology innovation ability and sort it out.

3. Model Optimization by Weight Coefficient Method

Given that the random variable $x = (x_1, x_2 \dots, x_n), (m \geq 1)$ is one feature of the uncertain information system, the probability value is p_i, $0 \leq p_i \leq 1, (i = 1,2,\cdots,m)$, and satisfy $\sum_{i=1}^{m} p_i = 1$, the entropy of grey system is defined as [13-14]:

$$E = -\sum_{i=1}^{m} p_i \ln p_i. \tag{5}$$

After the original index quantization, the standard index value p_{ij}:

$$p_{ij} = r_{ij} / \sum_{i=1}^{m} r_{ij}. \tag{6}$$

For r_j, the information entropy E_j:

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}, (0 \leq E_j \leq 1). \tag{7}$$

The weight coefficient of "j" indicator is:

$$u_j = (1 - E_j) / \sum_{j=1}^{n} (1 - E_j), (0 \leq u_j \leq 1, \sum_{j=1}^{n} u_j = 1). \tag{8}$$

The formula (4) can be turned into:

$$w_i = \sum_{j=1}^{n} (1 - E_j) / \sum_{j=1}^{n} (1 - E_j) \varepsilon_{ij}. \tag{9}$$

The formula shows: the probability of each assumption in this paper is equal, namely $p_i = 1/m, (i = 1,2,\cdots,m),$ at this point, entropy can obtain the maximum value:

$E_{\max} = \ln m$; r_{ij} in formula (6) is the " j " index value in the " i " enterprise; in the formula (7), $k = \frac{1}{\ln m}$.

4. Model Applications

The project team, according to the market research and related theory [15-17], establishes the index system of enterprise technology innovation ability as shown in Table 1:

Table 1. Technological Innovation Ability Index System

Factor	Indicator	Indicator type
Decision-making capacity	Innovation frequency	Quantification
	Innovation success rate	Quantification
Manufacturing capacity	Advanced level of production equipment	Quantification
	Proportion of new equipment	Quantification
	Proportion of skilled worker	Quantification
Marketing ability	Proportion of marketing personnel	Quantification
	Proportion of channel	Quantification
	Proportion of advertisement	Quantification
Factor	Indicator	Indicator type
R&D capacity	R&D cycle of new products	Quantification
	Proportion of new product sales	Quantification
	Proportion of R&D expenditure	Quantification
	R&D success rate	Quantification
	Proportion of R&D personnel	Quantification
Employee capacity	Employee's quality proportion	Quantification
	Employee growth ability	Quantification
	Informationization degree	Quantification

There are seven enterprises, a, b, c, d, e, f, g; their various index values are as shown in Table 2:

Table 2. Quantitative Indicators of Seven Enterprises

Enterprise indicator	A	B	C	D	E	F	G
1	73	87	63	57	55	98	69
2	69.57	92	64.2	50	61	82	72
3	0.51	1.53	0.34	0.44	0.42	6	0.9
4	83	87	78	81	76	89	82
5	0.62	0.94	0.61	0.9	0.73	5.4	1.96
6	0.53	0.5	0.13	0.2	0.23	0.3	0.42
7	25.96	33.16	10.91	19.78	20.34	40	36
8	72.27	72.9	72.39	77.27	68.81	92.15	75.5
9	1.95	16.78	18.4	28.83	10.38	91	14
10	62.23	63.5	56.4	63.8	57.6	76	53
11	7.63	10.12	4.12	10.12	7.04	15.6	5.2

12	49.16	124.33	309.52	83.25	77.5	426.24	377.36
13	2.42	2.13	2.1	4.99	3.76	12.2	2.6
14	0.51	0.5	0.38	0.49	0.46	2.72	1.05
15	0.054	0.042	0.031	0.039	0.038	0.086	0.07
16	0.022	0.033	0.015	0.019	0.024	0.078	0.045

Note: the quantitative index values shown in Table 2 can be got from the various accounting data and statistical data of the enterprise.

Here, $k = \frac{1}{\ln 7}$, use Excel to calculate the information entropy [18-19] E_j and weight u_j, as shown in Table 3:

Table 3. The Information Entropy and Weight Coefficient of Each Indicator

Indicator	1	2	3	4	5	6	7	8
E_j	0.8319	0.8346	0.6022	0.8394	0.6694	0.7789	0.8044	0.8350
uj	0.0412	0.0406	0.0976	0.0394	0.0811	0.0542	0.0480	0.0405
Indicator	9	10	11	12	13	14	15	16
E_j	0.6337	0.8379	0.8040	0.7037	0.7285	0.7001	0.6843	0.6343
uj	0.0898	0.0398	0.0481	0.0727	0.0666	0.0735	0.0774	0.0897

According to the grey relational analysis evaluation method, set Y_0 as the evaluation criteria:

Y_0=(1.0000,1.0000,1.000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1 .0000,l.0000,l.0000,1.0000,l.0000,1.0000,1.0000)

Then:

$$\min_i \min_j \left| y_{0j} - y_{ij} \right| = 0. \tag{10}$$

$$\max_i \max_j \left| y_{0j} - y_{ij} \right| = 1. \tag{11}$$

As $\rho = 0.5$:

$$\varepsilon_{ij} = 0.5/(\left| y_{0j} - y_{ij} \right| + 0.5). \tag{12}$$

According to the formula (3), the correlation coefficient ε_{ij} of each enterprise can be obtained (as shown in Table 4):

Table 4. Indicator Correlation Coefficient ε_{ij}

Enterprise indicator	A	B	C	D	E	F	G
1	0.4624	0.6615	0.3805	0.3440	0.3333	1.0000	0.4257
2	0.4835	1.0000	0.4303	0.3333	0.4038	0.6774	0.5122
3	0.3401	0.3877	0.3333	0.3373	0.3365	1.0000	0.3569
4	0.5200	0.7647	0.3714	0.4483	0.3333	1.0000	0.4815
5	0.3338	0.3494	0.3333	0.3474	0.3390	1.0000	0.4105
6	0.3333	0.3509	1.0000	0.7407	0.6667	0.5405	0.4082
7	0.5088	0.6801	0.3333	0.4184	0.4252	1.0000	0.7843
8	0.3699	0.3774	0.3713	0.4395	0.3333	1.0000	0.4121
9	0.3333	0.3750	0.3801	0.4173	0.3558	1.0000	0.3664

10	0.4551	0.4792	0.3698	0.4852	0.3846	1.0000	0.3333
11	0.4187	0.5116	0.3333	0.5111	0.4014	1.0000	0.3556
12	0.3333	0.3844	0.6176	0.3547	0.3509	1.0000	0.7941
13	0.3405	0.3340	0.3333	0.4119	0.3744	1.0000	0.3447
14	0.3462	0.3451	0.3333	0.3441	0.3411	1.0000	0.4120
15	0.4622	0.3846	0.3333	0.3691	0.3642	1.0000	0.6322
16	0.3600	0.4118	0.3333	0.3481	0.3684	1.0000	0.4884

Finally, according to the formula (9), calculate the weighting relevancy (see Table 5) of each enterprise against the optimal reference, and the enterprise technological innovation capability evaluation system ranking list (see Table 6).

Table 5. Enterprise Relevancy w_i

	A	B	C	D	E	F	G
Wi	0.0191	0.0273	0.0157	0.0142	0.0137	0.0412	0.0175

Table 6. Enterprise Technological Innovation Capability Ranking List

Ranking	1	2	3	4	5	6	7
Enterprise	F	B	A	G	C	D	E

The above ranking and the macroscopic evaluation result is consistent, showing that the built evaluation model of enterprise technology innovation system capability is effective, and it can offer the clear innovation ability data value of different enterprises (the optimum reference value), providing the useful decision-making reference for the enterprise technology innovation system, the optimization technology cooperative system.

5. Conclusion

This paper, based on the self-organization theory and collaborative theory, puts forward the focus issue faced by the enterprise technology innovation capability evaluation system, points out that its essence is the evaluation of complex systems, uses the grey relational analysis model and the weight coefficient method to optimize. Finally, use the optimization model to comprehensively evaluate the technological innovation ability of the seven enterprises, providing the beneficial exploration for enterprises to promote technology innovation and improve the technological innovation effect.

Because of the limitation of subjective and objective conditions, some issues in this paper remains to be studied further: there is no further discussion for the dynamic evolution of the model, that is, the enterprise is in different development stages in life cycle, the technology innovation evaluation system has different characteristics, how to set the index coefficient[20], and the dynamic change of enterprise technology innovation ability, *etc*., which remain to be explored further in the future.

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References

[1] W. B. Zhang, “Synergetic economics. Time and change in non-linear economics”, Berlin: Springer-Verlag, **(1991)**, pp. 261.

[2] H. Haken, “Synergetics, an Introduction: Non-equilibrium Phase Transitions and self-Organization in Physics, Chemistry, and Biology, 3rd rev. enl. Ed”, New York: Springer-Verlag, **(1983)**.

[3] A. Bolourchi, S. F. Masri and O. J. Aldraihem, “Development and application of computational intelligence approaches for the identification of complex nonlinear systems”, Nonlinear Dynamics, vol. 79, no. 2, **(2015)**, pp. 765-786.

[4] H. Haken, “Synereetics, its microscopic and macroscopic foundation, In: Caghoti G. Haken H. (eds) Synergetics and dynamic instabilities”, Proceedings of the International School of Physics. North-Holland, Amsterdam, **(2000)**.

[5] P. Jisheng and W. Linhai, “Technical collaborative innovation model and structure”, Research and development management, vol. 12, no. 5, **(2000)**, pp. 12-16.

[6] M. Milano and M. Lombardi, “Strategic decision making on complex systems”, Constraints, vol. 19, no. 2, **(2014)**, pp. 174-185.

[7] W. Binghong, Z. Tao, W. W. Xu, Y. H. Jie, Z. Ming, Y. C. Yang, H. Y. Pu and X. Y. Bo, “The research directions of current complex systems”, Complex systems and complexity science, vol. 5, no. 4, **(2008)**, pp. 21-28.

[8] S. B. Chen, Z. D. Hu and M. Zhang, “The Feasible Coalitional Structures in the Weighted Cooperative Games”, Applied Mechanics and Materials, vol. 713-715, **(2015)**, pp. 1963-1966.

[9] F. Huettner, “A proportional value for cooperative games with a coalition structure”, Theory and Decision, vol. 78, no. 2, **(2015)**, pp. 273-287.

[10] W. Yunjie and G. Yaolu, “Grey relational degree evaluation of listed corporate business performance in Shanxi Province”, Journal of Xi'an Engineering University, no. 4, **(2006)**, pp. 463-466.

[11] J. Montmain, C. Labreuche, A. Imoussaten and F. Trousset, “Multi-criteria improvement of complex systems”, Information Sciences, vol. 291, no. 10, **(2015)**, pp. 61-84.

[12] X. Yi, “Application of entropy weight coefficient method to the evaluation of the profitability of listed firms”, Computer Application and System Modeling, Coll. of Econ. & Manage., Heilongjiang Bayi Agric. Univ., Daqing, China; Xiaotong Zhu, vol. 5, **(2010)**, pp. 108-110.

[13] G. Xianguang, “Improved entropy method and its application in economic benefit evaluation, System engineering theory and practice”, no. 12, **(1998)**, pp. 98-102.

[14] Z. Weimin, “Urban sustainable development evaluation model based on the entropy evaluation method”, Journal of Xiamen University (philosophy and social sciences edition), no. 2, **(2004)**, pp. 109-115.

[15] G. Azar and R. Drogendijk, “Psychic Distance, Innovation, and Firm Performance”, Management International Review, vol. 54, no. 5, **(2014)**, pp. 581-613.

[16] Z. Connie, “The inner circle of technology innovation: a case study of two Chinese firms”, Technological forecasting and social change, vol. 82, **(2014)**, pp. 140-148.

[17] G. Medda and C. A. Piga, “Technological spillovers and productivity in Italian manufacturing firms”, Journal of Productivity Analysis, vol. 41, no. 3, **(2014)**, pp. 419-434.

[18] B. Michael, M. Robin, M. Paolo and S. Kiril, “Entropy, complexity, and spatial information”, Journal of Geographical Systems, vol. 16, no. 4, **(2014)**, pp. 363.

[19] S. Spiekermann and J. Korunovska, “The importance of interface complexity and entropy for online information sharing”, Behaviour & Information Technology, vol. 33, no. 6, **(2014)**, pp. 636-645.

[20] C. S. Tapiero and P. Vallois, “Financial Modelling and Memory: Mathematical System”, Future Perspectives in Risk Models and Finance, International Series in Operations Research & Management Science, vol. 211, **(2015)**, pp. 149-246.

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