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# **An Empirical Study on Performance Evaluations of Regional Innovation System Based on Management Entropy Theory**

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**Abstract:** The performance evaluation of the regional innovation system (RIS) based on the management entropy theory can dynamically describe its overall innovation level and its development trend. This article describes the content of management entropy theory and analyzes its function mechanism of the RIS. On the basis of above, this article establishes its own index evaluation system and entropy evaluation model. At last, the empirical analysis of Hebei province is taken to support the theory.

**Keywords:** Regional Innovation System; Management entropy; Performance evaluation

## **1. INTRODUCTION**

The concept of entropy originated in classical thermodynamics theory. It is presented by a German physicist, Clausius, in 1865 with the second law of thermodynamics. It is described as "in the isolated system of actual process, the whole system of the numerical value of the entropy always increases and it is irreversible. This is the entropy increase principle". Ren Peiyu brought entropy theory in management science and got the management entropy. The application of management entropy theory to measure and evaluate the performance of the regional innovation system is a frontier research of the performance evaluation system at home and abroad. Through the analysis of the change of the total entropy value of the regional innovation system, the positive entropy and the negative one, we can dynamically measure its overall innovation level and its development trend. It is very important to integrate the regional innovation resources and improve the sustainable innovation ability of this region.

There is not much recorded in foreign literatures about the performance evaluation of regional innovation. The United States is the earliest country to carry out the research of innovation index system. OECD puts forward the guiding principle of collecting and explaining innovation data. The European Union evaluates the innovation ability of its members from the investment in science and technology and the performance of them. This index system emphasizes the important role of human resource in innovation creativity. Chinese scholars mostly use factor analysis, the production function, data envelopment analysis (DEA) to create quantitative evaluation index system. Meng Yuming uses the fuzzy mathematics theory to construct index evaluation system to evaluate regional technology innovation ability. Wang Haisheng and Zheng Liqun use the production function of regional innovation system performance to measure it and take Shanghai as an example to make an empirical study. Li Zongzhang and Wu Xianying apply the method of factor analysis to make a quantitative analysis and evaluation on our country's regional technology innovation ability respectively. Liu Shunzhong and Guan Jiancheng use DEA to evaluate innovation performance in each area of our country. Overall, most scholars at home and abroad use linear technology to make static analysis on targets from different angles and each method has its advantages, but they failed to clear the operational mechanism of complex system from the perspective of regional innovation system. So it is unavoidable to be lack of the research of each index dynamic development and configuration cooperation capacity between indexes in the evaluation index system design, selection and the operation of evaluation methods, thus, it can not be a comprehensive and dynamic object to reflect the current

situation and the trend of development.

Regional innovation system is a complex, nonlinear, and of self-organizing feature's open system. In the internal system, each element interacts and restrains from each other and form a hierarchical structure. The innovation operation performance and sustainable development of the regional innovation system depend on the organization system function and the interaction of system and environment mutually. Management entropy evaluation considers the influence of many internal and external factors of system development and their interactions from the view of complex system, establishes management entropy model and dynamic quantitative evaluation, finally judge the present situation and the trend of the system development, which makes performance evaluation more in-depth and more objective.

## **2 The CONNOTATION AND FUNCTION MECHANISM OF REGIONAL INNOVATION SYSTEM MANAGEMENT ENTROPY**

### **2.1 The connotation of regional innovation system management entropy**

Management entropy (Ren Peiyu, 1997, 1998, 2001) is what shows isolated and closed system evolution full of uncertainties and chaos because of the organization's complexity and the complexity of the environment, and makes effective energy descend, invalid energy increase, system from orderly development to disorder and the system efficiency decrease. This is the process of system entropy increase. The increase of system entropy leads isolated system efficiency and its order to diminishing and gradual going to decline and fall. But an open system far from the balance state can mutate when the external conditions achieve at a certain threshold through the continuous exchange of material, energy, letter urgent with external environment. The original chaos will turn into a new kind of orderly structure in time, space and function. This is the increase process of negative entropy and also the process of forming management dissipative structure (Ren Peiyu, 1997).

The change of management entropy value reveals the direction and degree of the system development. The performance of regional innovation system and its development trend is also decided by the interaction and influence of the law of management entropy and management dissipative interaction. If the regional innovation system entropy is increasing or positive, it shows that the system is in a mess, the system performance will down and gradually decline, which is a result of an disorder interaction between the main elements of inner system, but if the system continuously introduces energy from outside and material to offset system of internal interaction disorder, then the internal system's positive entropy decreases and negative one increases, the system enters order and form the dissipative structure. Forming a dissipation structure is the key to the sustainable development of the regional innovation system.

### **2.2 The function mechanism of regional innovation system management entropy**

In the process of regional innovation system's evolution, the main elements are different from innovation demand and supply situation. Under the drive of the demand mechanism, innovative factors will flow through the ways such as cooperation development, informal communication, technical diffusion, personnel channels and so on, and the system will form a primary "small fluctuations". But as time goes on, each innovation subject develops inconsistently in technology, knowledge, institution and service because of the complexity of the system itself. It also results in the dislocation of the behavior of innovation and makes an obstacle to innovation. In addition, the not controlled factor from outside world keep inputting, it is difficult for system to control around the goal. In the prospect of function, it presents disorder in some ways and the system formed a bottleneck effect, into a chaos of ineffectiveness and disorder. The specific performance is the exhaustion of innovation resource, poor management, and low system innovation efficiency and so on. But because of that any objective existence of the system can not be a absolutely closed system, regional innovation system will exchange material and energy constantly with surrounding environment based on the demand of innovation.

When the surrounding environment changes, such as under the action of adjacent regional innovation demand changes, relevant government innovation policies introduces, innovation infrastructure changes, new knowledge produces and so on, the system continuously introduces new knowledge and resources from the surrounding environment and each regional innovation subject will speed up the update of system bottlenecks through interactive learning, form a strong innovation field to offset chaos generated from the system internally. At this time, the system enters into an orderly state again and forms a dissipative structure. As soon as this system forms, a random disturbance in the system will be enlarged through the related functions and develop into a whole, macro and great fluctuation, which makes organization into an unbalanced state and up to a new stable and orderly state through the organization role again after reaching at a certain threshold, then forms a kind of highly efficient structure of organization.

### 3 Management Entropy Evaluation Model of Regional Innovation System Performance

The main idea of regional innovation system performance management entropy evaluation is to screen the index of traditional performance evaluation under the guidance of the theory of management entropy, to measure system entropy value by constructing the comprehensive performance evaluation system based on the management entropy and reflect the status of evaluation object and development trend comprehensively and dynamically according to the change of entropy value. Its purpose is to find the main factors that restricts the improvement of regional innovation system performance and take measures to minimize the entropy increase phenomenon exists in the innovation, to make the system develops to the direction of negative entropy, orderly and efficiency.

#### 3.1 Selection of evaluation index of regional innovation system performance

According to the theory of management entropy, the total entropy value of a complex system of is the aggregation of its subsystem entropy. The overall performance of regional innovation system is decided by several subsystems through the nonlinear interaction of each other, and each subsystem performance is restricted in the internal dynamic action of its several factors. Thus, before we measure the whole performance entropy value of the system, we should determine the impact factors of the system and subsystem entropy value. This article establishes a regional innovation overall performance evaluation system of five subsystems like system innovation structure performance, system innovation investment performance, system innovation technology benefit performance, system innovation economic performance, system innovation social performance and so on the basis of summarizing the relevant domestic and foreign studies. We respectively use structure entropy, input entropy, technical benefit entropy, economic benefit and social benefit entropy to express subsystem entropy value and choose specific evaluation index to form a total entropy value parameter form of regional innovation system performance evaluation. As table 1 show,

**Table 1 Total entropy value parameter form of regional innovation system performance evaluation**

Total Entropy Value Parameter	Structure Entropy A1	Quantity of Higher School B11
		Quantity of Research Institutions B12
		Quantity of High-tech Enterprises B13
	Input Entropy A2	Founds of R&D (Hundred Million Yuan) B21
		Proportion of The Founds of R&D in GDP B22

Form Of Regional Innovation Performance, x1		Expenditure of The Funds of R&D in Large and Medium-sized Enterprises (Hundred Million Yuan) B23
		Proportion of Government of Science and Technology Funding in Financial Expenditure B24
		Totality of Technician (Ten Thousand) B25
	Technical Benefit Entropy A3	Number of Patent Application B31
		Number of Patent for Authorization B32
		Number of Scientific and Technological Achievements B33
		Number of Published Scientific Papers (Ten Thousand) B34
		Volume of Transaction in Technology Market (Hundred Million Yuan) B35
	Economic Benefit Entropy A4	Volume of Export of High-tech Products (Hundred Million Yuan) B41
		Regional Per Capita GDP (Ten Thousand) B42
		Growth Rate of Regional GDP B43
	Social Benefit Entropy A5	Control Rates of Industrial Waste Water Discharge B51
		Rate of Multipurpose Utilization of Industrial Solid Wastes B52
		Social employment (Ten Thousand) B53
		Droop Rate of Energy Consumption Per Unit Product (%) B54

### 3.2 Constructing Regional Innovation System Performance Management Entropy Evaluation Model

According to the management entropy theory and the Total Entropy Value Parameter Form of Regional Innovation System Performance Evaluation, this article construct an entropy evaluation model of regional innovation system performance management:

$$D_s = \sum_{i=1}^n w_i d_{si} \quad (1)$$

$$d_{st} = \pm K_B \sum_{j=1}^m p_j \ln p_j \quad (2)$$

$$K_B = (\ln m)^{-1} \quad (3)$$

$$P_j = \frac{x_i}{\sum_{j=1}^m x_j} \quad (4)$$

In (1),  $i$  stands for interacted subsystems in the regional innovation system.  $w_i$  is the weight of each subsystem, as the same meaning of the probability of impact to the overall regional innovation performance. Considering that the weight is hard to be objectively calculated, we take the method of experts' group decision, establish a set of weight assessment and take the method of information entropy weight correction to determine the final weight.  $D_s$  stand for the total entropy value of the system.

In (2),  $d_{st}$  is the entropy value of subsystems, as the same meaning of entropy value of the main influence

factors.  $j$  is those main factors influence the performance of each subsystem in the subsystem. When the impact factors are internal factors of the system and an obstacle to the development of the system, the volume of (2) is positive. When the impact factors are external factors of the system and the energy and materials absorbed from external environment into the system, the volume of (2) is negative.

In (3),  $K_B$  is the entropy value coefficient of each subsystem.

In (4),  $P_j$  is the probability of effects that each main factors influence  $d_{st}$  in the subsystem.  $\sum_{j=1}^m P_j = 1$ .  $x_j$  is the value of the impact factor.  $m$  is the number of impactor factors in each subsystem.

#### 4 EMPIRICAL ANALYSIS OF THE MANAGEMENT ENTROPY PERFORMANCE EVALUATION OF REGIONAL INNOVATION SYSTEM IN HEBEI PROVINCE

This article takes regional innovation system in Hebei province as an example. We establish an index system of regional innovation performance evaluation according to Table 1, select sample value of each index data and use the management entropy evaluation model of regional innovation system performance on the base of the compositing of experts' evaluation to determine the weight and using the industry standard data to correct the sample volume to calculate the total entropy value of regional innovation system performance in Hebei province, as Table 2 shows. Considering the timeliness and the possibility of obtaining the data, we separately choose the 2007, 2008 annual data from Hebei technology statistics site, Hebei statistical site, China statistical yearbook as the sample data. The specific procedure is as follows:

(1) Establishing an index system of regional innovation performance evaluation in Hebei province. According to Table 1, we select indicator sample data, take standardization processing to the sample data, calculate the volume of revised index  $x_i$ .  $x_i$  is the result of the standard volume of industry divided by  $S_j$ . And the standard volume of industry is from China statistical yearbook and China science and technology statistics site.

(2) Using the information entropy weight correction method to determine the weight of each subsystem  $w_i$ . Considering that the subsystem of the weight of each subsystem is obtained by the expert scoring method, which is of subjectivity in some ways. But using the information entropy weight correction method is by the measure of original data entropy, which create the necessary objective weight automatically with the dynamic change of each evaluation objective, which has eliminated the influence of subjective factors.

We assume that the number of the evaluation index is  $m$ , the quantity of evaluation index value that experts give for each index is  $n$ ,  $a_{ij}$  stands for the NO. $j$  evaluation index value of the NO. $i$  evaluation index, and they form a matrix of evaluation index value as  $A = (a_{ij})_{m \times n}$ . We obtain the information entropy of each index, as the formulation shows:

$$p_{ij} = \frac{a_{ij}}{\sum_{j=1}^n a_{ij}}, \quad \sum_{j=1}^n p_{ij} = 1, \quad i=1,2,3, \dots, m; j=1,2,3, \dots, n$$

$$e_i = -k \sum_{j=1}^n p_{ij} \ln p_{ij}, \quad k = \frac{1}{\ln n}, \quad 0 \leq e_i \leq 1$$

So, The corrected weight of information entropy of  $i$  is,

$$w_i = \frac{1 - e_i}{m - \sum_{i=1}^m e_i}.$$

We can see that if the entropy of an index is smaller, it means the degree of variation of that index is greater, the information offered is more, the role of it in the performance evaluation system of regional innovation is larger and its weight is bigger. On the contrary, the weight is smaller.

(3) Calculating the entropy value of each subsystem and the total entropy value of the system, and the contribution rate of the entropy value of subsystem. The contribution rate of each subsystem to the change of the total entropy value = The variation of management entropy of each subsystem / The variation of total entropy of the system

**Table 2 The Measurement Table of The Entropy Value of The Regional Innovation System Performance Evaluation in Hebei Province**

		Year 2007				Year 2008				Contribution Rate of the Entropy Value of Subsystem
		$S_i$	$x_i$	$w_i$	$d_{si}$	$S_i$	$x_i$	$w_i$	$d_{si}$	
A1	B11	88	1.46	0.19	-0.899	105	1.46			1.04
	B12	104	0.87			107	0.9			
	B13	655	0.42			668	0.39			
A2	B21	90	2.2	0.23	-0.874	109	2.41	0.23	-0.854	2.80
	B22	0.66	0.57			0.67	0.56			
	B23	54.9	0.47			72.9	0.49			
	B24	1.19	0.51			1.13	0.48			
	B25	13.6	0.93			14.3	0.88			
A3	B31	7853	0.43	0.21	-0.559	9128	0.41	0.21	-0.601	-17.08
	B32	5358	0.59			5496	0.51			
	B33	2479	0.53			3049	0.54			
	B34	3.68	0.9			3.48	0.73			
	B35	16.4	7.32			16.6	5.74			
A4	B41	27.8	0.25	0.18	-0.878	35.8	0.27	0.18	-0.900	-2.41
	B42	2.32	1.05			2.43	0.94			
	B43	17.57	0.89			16.91	0.89			
A5	B51	92.28	1.07	0.19	-0.584	95.48	1.1	0.19	-0.582	0.23
	B52	54.98	9.8			64.53	9.8			
	B53	3657	1.59			3651	1.55			
	B54	4.02	0.51			6.29	0.53			
Total Entropy Value of The System			-0.60018				-0.7643			

Data from: 2007 and 2008 years Hebei statistic site, Hebei Science and Technology Site, China Statistic Yearbook

From Table 2, we can see that Because of the increase of regional investment innovation of 2008 and the quantity of research institutions and innovative enterprises, the ordered degree and the performance of the regional innovation system has been greatly improved, and the management entropy value has been reduced. The innovation investment subsystem to the improvement of the regional innovation performance made the

largest contribution. But the regional innovation system technology benefit and the economic benefit is poorer, falling behind the average level in the industry, and has played a curbing role to the improvement of the regional innovation performance.

## 5 CONCLUSION

The innovation performance of the regional innovation system is mutually determined by the interaction of each element in the system and the interaction of system and environment. So, using the management entropy evaluation model of the regional innovation system can reflect the overall performance and the development trend of the system scientifically and dynamically. By the way of calculating the performance entropy value of each subsystem of the regional innovation system and finding out the key factor to produce the maximum entropy value and the minimized one, it can help the government to find out the bottleneck factors that restrict the improvement of the innovation performance, providing important basis for us to optimize the allocation of resources further and make a scientific decision. But as the evaluation of the performance of the regional innovation system by management entropy is a relatively new topic, some links are to be improved in the future.

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