Construction and Application of Comprehensive Evaluation Index System for Long-Term Cooperation Between Enterprises, Universities and Research Institutes

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Abstract

In the process of industry-university-research institute cooperation, it is of vital significance to construct a set of comprehensive evaluation index system which can objectively and effectively reflect the performance of industry-university-research institute cooperation for promoting the long-term cooperation among the three parties. This paper regards industry-university-research institute cooperation as an input-output system, and constructs a comprehensive evaluation index system which includes four first-level indexes of initial input, cooperative process, cooperative output and re-input. On this basis, a reasonable evaluation model is constructed to comprehensively evaluate the performance of industry-university-research cooperation from three aspects: cooperation scale, cooperation efficiency and cooperation sustainability.

Keywords: industry-university-research long-term cooperation, index system, input-output, analytic hierarchy process, standard deviation method

Since 1990's, knowledge economy rises in a global scope. As an important mode of technological innovation, industry-university-research cooperation has gradually become a broad consensus of various countries in its important position and significance in the process of economic development. At present, China is in the critical period of transforming from extensive economy to intensive economy and building an innovative country. The efficient interaction among enterprises, universities and scientific research institutes is gradually becoming an effective driving force for technological innovation.

At present, domestic industry-university-research cooperation is presented in a variety of forms. For instance, enterprises develop scientific achievements in cooperation with universities or research institutes; scientific and technological achievements in colleges and universities or research institutions entrusted by enterprises; universities or research institutions directly transfer technical achievements; enterprises and universities or research institutions found research and development institutions; enterprises and universities or research institutions undertake the national projects, etc.. To investigate the overall effect of so many different forms of cooperation, it is imperative to find a set of comprehensive evaluation index system that can objectively and effectively reflect the effect of industry-university-research cooperation.

1. The Basis of Index Selection

Industry-university-research cooperation refers to the process in which enterprises, institutions of higher learning and scientific research institutions invest manpower, material resources and financial resources, and each element of the system achieves a certain effect of cooperative innovation through the cooperation process, and finally converts into innovation performance output. In essence, it is an input-output system (as shown in Figure 1). In this process, enterprises become the demanders of technology due to their lack of technical resources and scientific research ability, and provide financial support and technology application platform for research and development in the combination. Although universities and scientific research institutions lack the platform of technology transformation and commercialization, their advantages in technology and human capital make them become the suppliers of technology and provide technical and human capital support in the combination. By combining the advantages of their own resources, the two sides achieve complementary advantages of resources. In addition, in order to form a

long-term cooperation mechanism among the three parties, all parties should also devote appropriate resources to a new round of cooperation, so that the cooperation among the three parties can be maintained in the long term, rather than taking a round of input-output process as the end of cooperation.

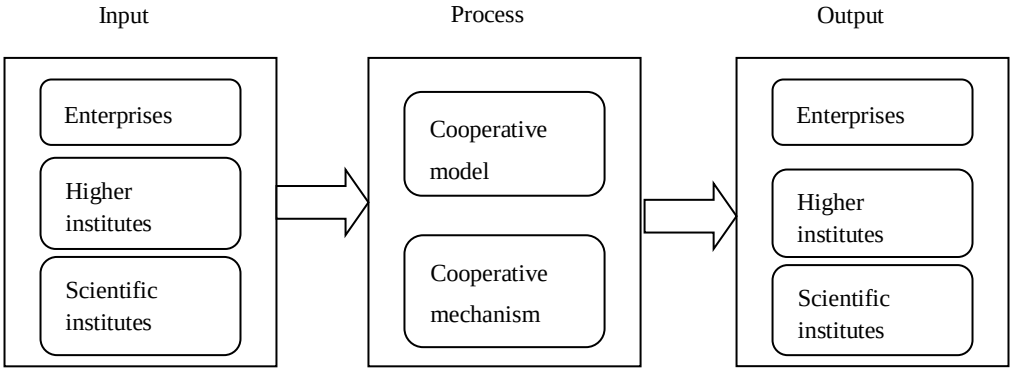

Figure 1. Industry-university-research cooperation process diagram

According to the above analysis, the comprehensive evaluation index system of industry-university-research cooperation should also be constructed from four aspects: initial input, cooperation process, cooperation output and re-input. Among them, the indicators of initial input, cooperative output and re-input are mostly measurable indicators, called hard indicators, which can be obtained through statistical data and investigation and evidence collection. However, the indicators of cooperation process are mostly cognition and judgment indicators that are difficult to quantify, called soft indicators, which need to be obtained through expert judgment.

2. The Principle of Establishing Index System

In order to ensure the scientificity of the evaluation index system, the necessary evaluation principles must be adhered to:

2.1 The Objectivity Principle

That is to say, the indexes should be able to reflect the essential attributes of industry-university-research cooperation, and the form should be able to reflect the actual content as far as possible, and the indexes should be set according to the actual situation of industry-university-research cooperation.

2.2 Comparability Principle

That is to say, the evaluation system should be applicable to different forms of industry-university-research institute cooperation evaluation. The indexes should be normative and continuous, and the selected indexes should be close to the existing standard indexes as far as possible, so as to make the quality results of different forms of industry-university-research institute cooperation comparable.

2.3 The Principle of Hierarchy

That is to say, the whole index system should be logical and clear. Usually, starting from the overall attribute of the evaluation object, it is divided into first-level index, second-level index and third-level index according to the principle of top-down and coarse to fine. Finally, it is the specific index that can be quantified.

2.4 Feasibility Principle

That is, indexes that are convenient for quantitative calculation and analysis should be selected as far as possible. For those aspects that cannot be directly quantified, qualitative indicators can be set, but the connotation and denotation of qualitative indicators should be accurate to avoid ambiguity.

2.5 Principle of Pertinence

That is to say, different and targeted evaluation indexes should be selected for different subjects of industry-university-research cooperation.

3. Construction of Comprehensive Evaluation Index System

This paper designs different evaluation systems according to the status and characteristics of different subjects of industry-university-research cooperation. Because the position and role of universities and research institutions in the process of industry-university-research cooperation are very similar, a unified evaluation system is designed for them. Finally, a comprehensive evaluation index system for enterprises and a comprehensive evaluation index system for universities and scientific research institutions are formed.

3.1 Construction of Enterprise Comprehensive Evaluation Index System

In essence, industry-university-research cooperation is a cyclic input-output process, and its merits and disadvantages should be evaluated from four aspects: initial input, cooperative process, cooperative output and re-input. Through analysis and summary, the hierarchy of enterprise comprehensive evaluation index system is shown in Figure 2.

3.1.1 Initial Input

In industry-university-research cooperation, enterprises are usually the demanders of technology and mainly responsible for providing R&D funds. The amount and timeliness of R&D funds are crucial to the success of R&D cooperation. In addition, enterprises should also invest the necessary scientific and technological personnel and machinery. The number of scientific and technological personnel and the number of machinery and equipment invested should also be weighted and averaged according to the level of scientific and technological personnel and the value of machinery and equipment.

3.1.2 Cooperation Process

The purpose of selecting "cooperation process" is to investigate whether the cooperation between industry, university and research institute runs smoothly from beginning to end and whether the cooperation is efficient. Specifically, it includes information communication, which reflects the frequency of communication and the unimpeded degree of information among all parties in the process of cooperation. The degree of coordination reflects the degree of coordination of all parties in the process of cooperation; The degree of honesty reflects the cooperative attitude of all parties, that is, the degree of honesty; The degree of importance reflects the degree of importance of the enterprise executives and the main leaders of the academic and research parties to the industry-university-research cooperation projects. The distribution of benefits reflects the satisfaction of all parties to the distribution of benefits.

3.1.3 Cooperative Output

As the demanders of technology in industry-university-research cooperation, enterprises participate in cooperation with the ultimate purpose of acquiring new technology or new process for the production of new products, so as to increase profits. Therefore, the cooperative output indicators of enterprises mainly include: the number of patents granted, the number of new products developed, the proportion of the sales revenue of new products in the total sales revenue of products, the number of professional and technical personnel trained and the number of various technical rewards obtained. The second-level indicators under the above cooperative output should also be given different weights according to their different levels, so as to obtain the comprehensive score of each second-level indicator.

3.1.4 Re-input

After the completion of a round of input-output process, enterprises should also carry out additional investment in industry-university-research cooperation. Specific indicators include: re-input of scientific and technological funds, re-put of scientific and technological personnel, and re-put of machinery and equipment. In the process of calculating the above indicators, a weighted average should also be carried out on the basis of taking into account the level of scientific and technical personnel and the value of machinery and equipment.

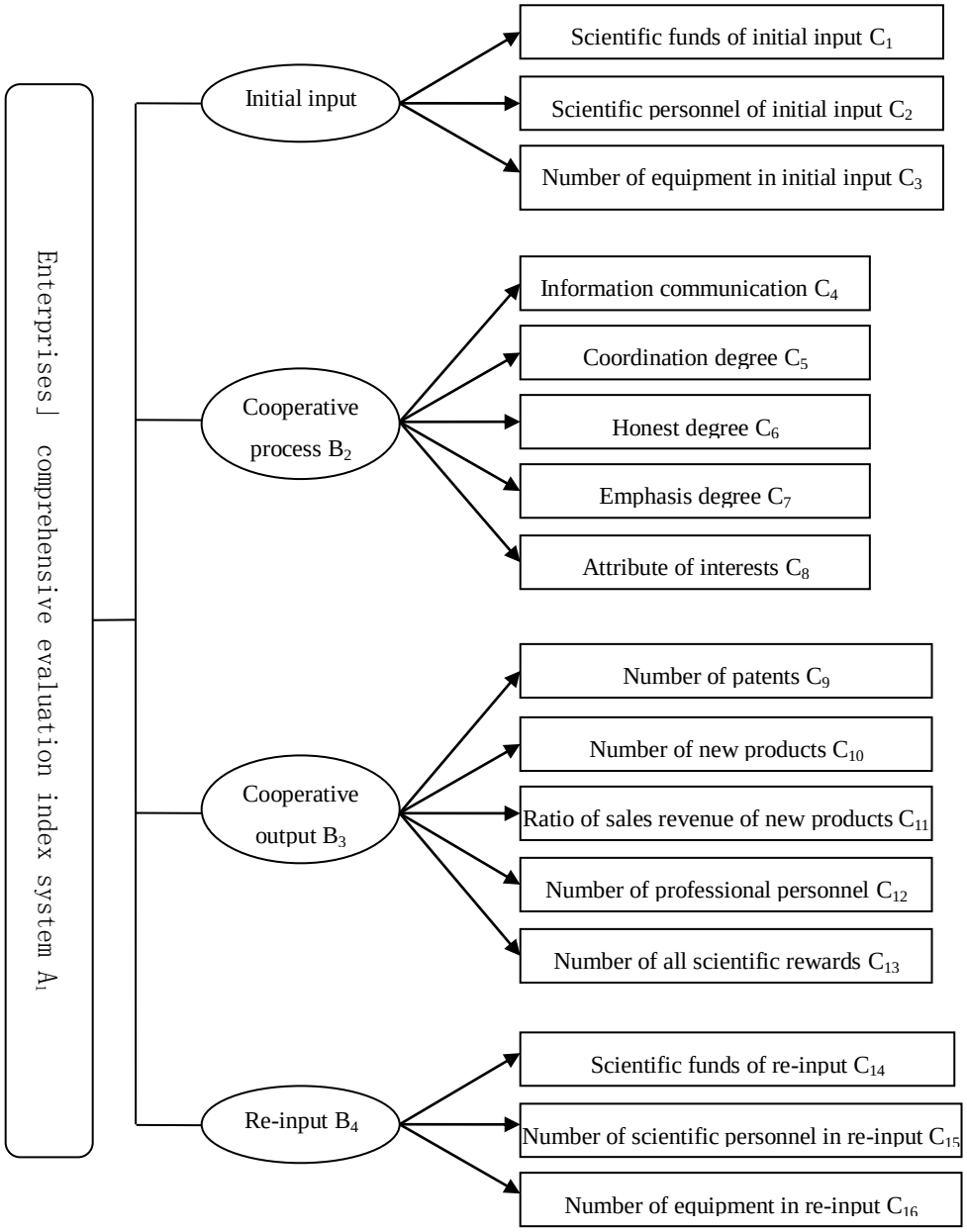

Figure 2. Enterprises' comprehensive evaluation index system

3.2 The Construction of Comprehensive Evaluation Index System of Universities and Research Institutions

The hierarchical structure of the comprehensive evaluation index system of universities and research institutions is shown in Figure 3.

3.2.1 Initial Input

In industry-university-research cooperation, the research party is usually the technology supplier. Its important responsibility is to invest human resources, carry out scientific and technological breakthroughs, and develop scientific and technological achievements. In addition, the research side should also train the relevant technical personnel of the enterprise for the use of the results.

3.2.2 Collaborative Process

In the process of industry-university-research cooperation, enterprises and university-research parties interact with

each other, so the evaluation indexes should be the same. The specific index composition has been introduced in Section 3.1, and will not be repeated here.

3.2.3 Cooperative Output

As the technology supplier in the cooperation, the ultimate purpose of the student-research party is to cultivate students' practical ability and improve their own research and development ability. Therefore, the indicators of cooperative output mainly include: the number of students trained, the number of patents granted, the number of published papers and works, the number of research and development projects, and the number of various scientific and technological rewards obtained.

3.2.4 Re-input

After the completion of a round of input-output process, the academic and research parties should also make additional investment in industry-university-research cooperation. The specific measurement indicators include: the number of scientific and technological personnel reinvested, the number of scientific and technological achievements reinvested, and the number of experimental instruments reinvested.

In the process of calculating the above second-level indicators, different weights should be determined according to their different levels, and then the comprehensive score of each second-level indicator can be obtained.

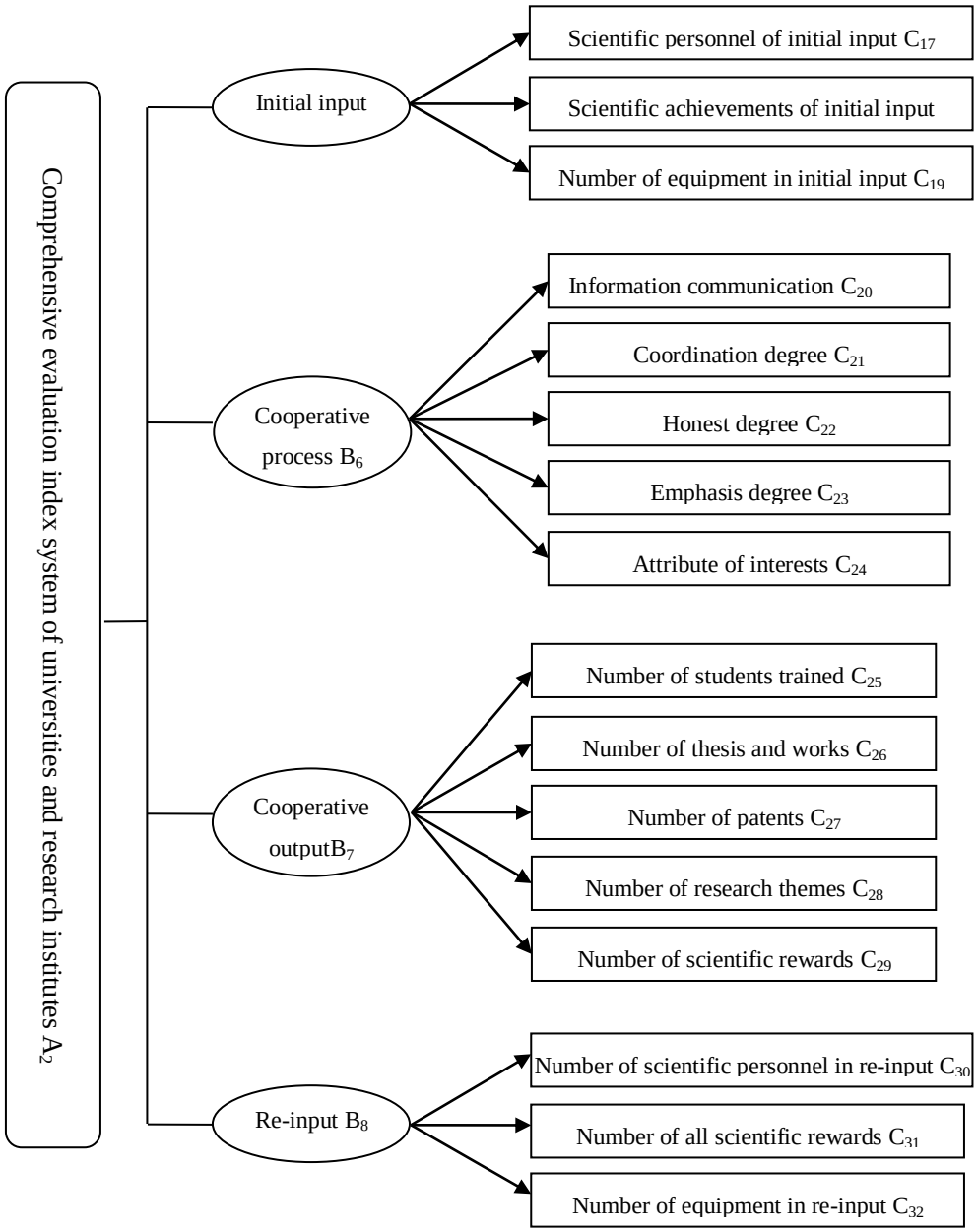

Figure 3. The structure of the comprehensive evaluation index system of universities and research institutes

4. Application of Comprehensive Evaluation Index System

The practical application of the above index system still needs to solve three problems: one is to determine the weight of each layer of indicators; The second is to assign values to each index; The third is to calculate the composite score.

4.1 Determine the Weight of Each Layer Index

In this paper, analytic hierarchy Process (AHP) is used to calculate the weight of each index. The judgment matrix of relative importance of index is constructed by 1-9 scale on the basis of widely solicits expert opinions. Through expert consultation, the relative importance of B layer factors and C layer factors is examined respectively, and the judgment matrix A can be obtained. Taking the calculation process of layer B index relative to the weight of layer A1 as an example, the calculation process is as follows:

$$\mathrm{A}=\begin{matrix}B_1\\B_2\\B_3\\B_4\end{matrix}\begin{bmatrix}a_{11} & a_{12} & a_{13} & a_{14}\\ a_{21} & a_{22} & a_{23} & a_{24}\\ a_{31} & a_{32} & a_{33} & a_{34}\\ a_{41} & a_{42} & a_{43} & a_{44}\end{bmatrix}$$

In the equation below,

$$\omega_i=\frac{\overline{\omega_i}}{\sum_{i=1}^{n}\overline{\omega_i}}=\frac{\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}$$

$\prod_{j=1}^{n}a_{ij}$ is the product of each row of the judgment matrix, and n is the order of the judgmentmatrix.

The relative weight coefficient of each factor can be obtained:

$$\omega=(\omega_1,\omega_2,\omega_3,\omega_4)^T$$

Then the maximum eigenvalue $\lambda_{\max}$ of the judgment matrix is calculated:

$$\lambda_{\max}=\sum_{i=1}^{n}\frac{(A\omega)_i}{n\omega_i}$$

Furthermore, we can get $\mathrm{CI}=\frac{\lambda_{\max}-n}{n-1}$

Thus, $\mathrm{CR}=\frac{\mathrm{CI}}{\mathrm{RI}}$.

When CR=0, Matrix A has complete consistency. When CR<0.1, we get satisfactory consistency. When CR≥0.1, we get unsatisfactory consistency. Thus, it should be adjusted or abandoned.

In addition, the comprehensive consistency of the index system should be calculated.

$$CI^*=\omega_1\times CI_1+\omega_2\times CI_2+\omega_3\times CI_3+\omega_4\times CI_4$$

$$RI^*=\omega_1\times RI_1+\omega_2\times RI_2+\omega_3\times RI_3+\omega_4\times RI_4$$

$$\mathrm{CR}^*=\frac{\mathrm{CI}^*}{\mathrm{RI}^*}$$

When CR*=0, The index system has complete consistency. When CR*<0.1, we get satisfactory consistency. When CR*≥0.1, we get unsatisfactory consistency. Thus, it should be adjusted or abandoned.

4.2 The Assignment of Each Index

In this comprehensive evaluation system of industry-university-research cooperation, the indicators of initial input, cooperative output and re-input are mostly measurable hard indicators, which can be obtained directly through statistical data and investigation and evidence collection. However, the indicators contained in the cooperation process are mostly soft indicators that are difficult to quantify and need to be obtained through expert judgment, which requires the design of a reasonable evaluation scale. (As shown in Table 1)

Table 1. Industry-university-research cooperation process evaluation scale

Content	Evaluation (1=not agree; 7=totally agree)						
In the process of cooperation, the other party can keep information open at any time	1	2	3	4	5	6	7
In the process of cooperation, the other party has made its due contribution to maintaining a good cooperative relationship	1	2	3	4	5	6	7
No breach or breach of trust by the other party	1	2	3	4	5	6	7
The other party's leaders paid enough attention to industry-university-research cooperation	1	2	3	4	5	6	7
The reward for the cooperation is reasonable	1	2	3	4	5	6	7

Note: "1" indicates disagreement with the description in the table, and the degree of agreement increases from "1" to "7", with "7" indicating strong agreement with the description.

As the academic team leaders of academic institutions and the chief engineers of enterprises are the most familiar with the entire process of industry-university-research cooperation, the academic team leaders of academic institutions are selected to fill in the scale to evaluate the performance of enterprises when evaluating the performance of enterprises in the process of industry-university-research cooperation. When evaluating the performance of the academic and research institutes in the process of industry-university-research cooperation, the chief engineer of the enterprise is selected to fill in the scale and evaluate the performance of the academic and research institutes.

5. Conclusions

As for the concept of industry-university-research cooperation, Turbin and Garrett believe that the cooperation between universities and enterprises is actually formed by heterogeneous organizations in order to realize the complementary advantages of their own resources. Some researchers have proposed that the heterogeneity of the cooperative subject and its resource endowment can only prove that the cooperative parties have the ability to cooperate, but does not guarantee that the parties automatically form the desire to cooperate. Only when the interests are driven, the cooperative parties have the initiative of cooperation. Industry-university-research cooperation is defined as the economic and social activities in which enterprises, universities and scientific research institutions cooperate with each other in the process of technological innovation, driven by interests and using their own resources to complement each other. The external environment will have a direct impact on the cooperation, so the external environment should be included in the definition of the cooperation.

This paper argues that integration of enterprise, university and research institution means that the three parties cooperate with their own advantageous resources, under support from the government and intermediary organizations. In the process of research and development, the advantages of their resources are combined with the factors of production. At the time when they obtain the expected benefits, they make their own resource advantages escalated further. Finally, the three parties stimulate the innovation and competitive advantage of the whole industry or region.

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