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Research on the Construction of Evaluation System for the Main Position of Enterprise led Industry University Research Collaborative Innovation

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Abstract: The study of the evaluation system for the dominant position of enterprises in collaborative innovation between industry, academia, and research is of great significance for guiding policies, promoting cooperation, and improving innovation efficiency. This article reviews previous research, based on the life cycle theory and the process perspective of enterprise participation in industry university research collaborative innovation, and proposes the main body status and evaluation system of enterprise led industry university research collaborative innovation, including four primary indicators of research and development investment, activity participation, scientific and technological achievements, and achievement benefits, and 18 secondary indicators. At the same time, principal component analysis and factor analysis were used to quantitatively analyze relevant indicators and variables, and the rationality of the enterprise led evaluation system for collaborative innovation between industry, academia, and research was sorted out. The research findings contribute to a better understanding of the impact of enterprise led collaborative innovation between industry, academia, and research on economic and social development, and provide guidance for future research and practice.

Keywords: Collaborative Innovation; Evaluation System; Industry Academia Research; Subject Status.

1. Introduction

Regarding educational technology talents, we must adhere to the "four orientations", strengthen collaborative innovation, promote deep integration of industry, academia, and research, and transform more scientific and technological achievements into practical productivity. Promoting the establishment of a technology innovation system that deeply integrates industry, academia, and research, with enterprises as the main body and the market as the guide, is the key path to solving the transformation of scientific and technological achievements and tackling technical difficulties. Nowadays, the country vigorously implements the innovation driven development strategy, attaches great importance to the collaborative innovation of industry, academia and research, and the "Thousand Schools, Ten Thousand Enterprises" collaborative innovation partnership action has emerged, aiming to promote innovation cooperation between universities and enterprises, and promote the deep integration of innovation chain and industrial chain. The Ministry of Education, the Ministry of Industry and Information Technology and the China National Intellectual Property Administration decided to jointly organize this action to strengthen the cooperation between universities and enterprises, promote the transformation of scientific and technological achievements and industrial upgrading. The policy system of "industry, university and research" cooperation in China has gradually improved, and gradually moved towards standardization and institutionalization [2].

The most effective way to promote national economic development is through technological innovation, and the key to achieving the strategic goals of an innovative country lies in building a technology innovation system that combines industry, academia, and research with enterprises as the main body. Industry university research cooperation must be led by enterprises, driven by market-oriented mechanisms to promote continuous technological innovation, and improve cooperation efficiency and effectiveness [3,4]. As for enterprises, they can participate in market competition and directly face the market, understand the innovative technologies and market demands of today's society, and thus determine the direction of industry university research cooperation. At the same time, in order to ensure the application and transformation of collaborative innovation achievements between industry, academia and research, enterprises must be the center of research and development, so as to better realize the value realization and market return of scientific and technological innovation. From this, it can be seen that the main body of collaborative innovation between industry, academia, and research is the enterprise, which oversees and controls the entire process of industry, academia, and research cooperation. Enterprise led collaborative innovation between industry, academia, and research represents the leading role of enterprises in organizing resources and conditions from all aspects, thereby achieving joint participation, cooperation, risk sharing, and benefit sharing among all parties in collaborative innovation. The application of collaborative research and development results to collaborative innovation activities in enterprises includes collaborative knowledge sharing, knowledge creation, and knowledge application.

2. Principles of Evaluation System Construction

2.1. The Necessity of Designing an Indicator System

In the development process of industry university research collaboration, many scholars have defined and elaborated on enterprise based collaborative innovation from different

perspectives. At the beginning of the 20th century, Austrian American economist J.A. Schumpeter first proposed collaborative innovation between industry, academia, and research, revealing the inevitable connection between corporate technological innovation activities and universities, research institutions, and private laboratories. The triple helix theory holds that in the era of knowledge economy, government, industry, and universities are the three core entities of innovation, and they jointly promote the evolution of knowledge towards technology, products, and industries, which is the spiral of innovation value. Although many scholars have studied and sorted out the influencing factors and operational mechanisms of the industry university research collaborative innovation system, there has been no research on the evaluation system of the subject status of industry university research collaborative innovation with enterprises as the main body. However, in recent years, under the strategic goal of building an industry university research collaborative innovation system with enterprises as the main body, how to enhance the dominant position of enterprises in the industry university research collaborative innovation system has become an urgent issue. Therefore, it is necessary to establish an evaluation system for the status of industry university research collaborative innovation entities with enterprises as the main body, mainly reflected in:

(1) Enterprises need to take a leading position in the industry university research collaborative innovation system, but it is still necessary to clarify in which processes and fields they need to be in a dominant position;

(2) Only by establishing an evaluation system for the status of enterprises as the main body of industry university research collaborative innovation can we guide enterprises to invest funds, manpower and other resources in industry university research collaborative innovation, promote their participation in industry university research collaborative innovation activities, and improve the efficiency of the formation, transformation and application of scientific and technological achievements;

(3) Enterprises are the main body that pushes the achievements of industry university research collaborative innovation towards marketization and industrialization. Therefore, only by forming an evaluation system for the status of industry university research collaborative innovation with enterprises as the main body, and promoting the rational allocation of funds and resources, can enterprises ensure the normal operation of technology collaborative innovation and market-oriented operation with universities and research institutes.

2.2. Design Principles of Indicator System

Scientificity. The structure of the evaluation system for enterprise led industry university research collaborative innovation follows the process of the front, middle, and later stages of industry university research [11]. Using principal component analysis and factor analysis methods, indicator elements are selected according to scientific standards and required data is obtained to construct a scientific evaluation system for the main position of enterprise led industry university research collaborative innovation.

Measurability. When constructing an evaluation system for the dominant position of enterprises in industry university research collaborative innovation, it is necessary to ensure that all indicators can be measured, and the final results can be scientifically determined whether enterprises have a dominant position in the industry university research collaborative innovation system.

Operability. The establishment of an evaluation index system for the status of the enterprise led industry university research collaborative innovation subject should have the following characteristics: relatively stable structure, open information acquisition, clearer data organization and changes, and different focuses at different stages, dynamically adjusted according to the development of the subject for further dynamic comparison. The data contained in the evaluation indicators should be easy to process and obtain, and the statistical caliber and scope of regional indicators should also be as consistent as possible.

typical. The evaluation system for the subject status of enterprise led industry university research collaborative innovation selects indicators from four aspects: R&D investment, activity participation, scientific and technological achievements, and innovation performance in the early, middle, and later stages of the industry university research process. The evaluation indicators have certain typical representativeness and reflect the subject status as accurately as possible in the enterprise led industry university research collaborative innovation system.

2.3. Design Ideas for the Evaluation System of The Subject Status of Enterprise Led Industry University Research Collaborative Innovation

The collaborative innovation activities of industry university research can be divided into pre stage, mid stage, and post stage, and the role of enterprises varies in different stages. In the early stage of the process of industry university research collaborative innovation, enterprises focus on selecting industrial technology innovation projects as key projects of the industry university research system, striving for preferential policies from the government for industry university research collaborative innovation projects, and creating an industry university research collaborative innovation system; In the middle stage of the collaborative innovation process between industry, academia, and research, enterprises invest in research and development, innovation, talent investment in the market, core technologies, and resource investment in coordinating government support. They participate in and lead the R&D innovation process in the collaborative innovation system between industry, academia, and research, and transform and obtain innovative results. In the later stage of the collaborative innovation process between industry, academia, and research, enterprises are in a dominant position in benefit distribution, achievement transformation, and market development. They allocate appropriate proportions of benefits in product development, basic research, and achievement transformation, and use achievements for technology application, market development, and commercial services, thereby realizing the formation of commercial value. Therefore, overall, in the industry university research collaborative innovation system with enterprises as the main body, the main role of enterprises is reflected in four aspects: R&D investment, activity participation, scientific and technological achievements, and achievement benefits.

2.4. Selection of Evaluation Indicators

The indicators for the evaluation system of the main position of enterprise led industry university research

collaborative innovation are mainly selected from four aspects: R&D investment, activity participation, scientific and technological achievements, and achievement benefits, as shown in the following figure:

Table 1. Evaluation System for the Main Position of Enterprise led Industry University Research Collaborative Innovation

First level indicator	Secondary indicators	Parameter layer
R&D investment	Capital investment	X11The proportion of industry university research and development funds invested by enterprises to the total research and development funds
		X12R&D expenditure intensity of enterprises (proportion of enterprise investment)
	Personnel input	X13Number of industry university research and development personnel (proportion)
		X14Number of industry university research and development teams (industry university research teams/independent teams)
		X15Growth rate of research and development personnel in industry, academia, and research
activity participation	System participation	X21The number of industry university research collaborative innovation systems initiated by enterprises
		X22The number of industry university research collaborative innovation systems in which enterprises participate
	Personnel participation	X23The number of personnel involved in collaborative innovation between industry, academia, and research in enterprises
		X24The number of teams participating in collaborative innovation between industry, academia, and research by enterprises
technological achievements	Achievement formation	X31The quantity of intellectual property rights with enterprises as the main body
		X32Number of authorized patents/number of R&D personnel
	Conversion application	X33The number of technological achievements transformed by enterprises as the main body
		X34The number of achievements applied by enterprises as the main body
	Ownership of achievements	X35The number of cooperative achievements whose usage rights belong to the enterprise
		X36The number of cooperative achievements with ownership belonging to the enterprise
achieving benefits	Technological benefits	X41The degree of technological innovation of the enterprise
		X42Prospects for Industrial Application of Technology
		X43Demonstration and driving degree of technological industry development

3. Construction of the Evaluation System for Subject Status

3.1. Evaluation Methods and Steps

3.1.1. Principal Components

Principal component analysis utilizes the idea of dimensionality reduction to transform multiple indicators into a few comprehensive indicators, which is a technique for simplifying datasets. In empirical research, researchers reduce the number of variables involved in order to obtain rich and effective information. To meet this requirement, principal component analysis has been developed, which can reduce the dimensionality of the data space being studied, delete redundant variables, and distinguish the relationships between variables.

The principal component analysis method includes the following five steps:

(1) Standardized collection of raw indicator data using p-dimensional random vectors x=(x1, X2,..., Xp) T) n samples xi=(xi1, xi2,...,xip) T,i=1,2,…,n, n>p, Construct a sample array and perform the following standardized transformations on the sample array elements: $r_{ij} = \frac{\sum z_{kj} \cdot z_{kj}}{n-1}, i, j = 1,2,\ldots, p$,wherein $\bar{x}_j = \frac{\Sigma_{i=1}^{n} x_{ij}}{n}, s_j^2 = \frac{\Sigma_{i=1}^{n}(x_{ij}-\bar{x}_j)^2}{n-1}$,We need to standardize the array Z.

(2) Calculate the correlation coefficient matrix for the standardized matrix Z

$R = [r_{ij}]_{pxp} = \frac{Z^T Z}{n-1}$, among, $r_{ij} = \frac{\sum z_{kj} \cdot z_{kj}}{n-1}, i, j = 1,2,\ldots, p$.

(3)Solving the characteristic equation of the sample correlation matrix R $|R-\lambda I_P| = 0$ Obtain p eigenvalues, Determine the principal components according to $\frac{\Sigma_{j=1}^{m}\lambda_j}{\Sigma_{j=1}^{p}\lambda_j} \geq 0.85$ Determine the value of m to achieve an information utilization rate of over 85%, for each λj, j=1,2, ..., m, Solving the system of equations Rb=λjb to obtain the unit eigenvector b_j^o .

(4)Convert standardized indicator variables into principal components $U_{ij} = z_i^T b_j^o, j = 1,2,\ldots,m$, U1 is called the first principal component, U2 is called the second principal component,..., Up is called the p-th principal component.

(5)The final evaluation value is obtained by comprehensively evaluating m principal components and weighting and summing them, with the weight being the variance contribution rate of each principal component.

3.1.2. Factor Analysis

Factor analysis is a multivariate statistical analysis method that studies the interdependence relationships within a matrix, transforming complex variable relationships into different composite factors [13]. The specific content is to distinguish variables of different sizes based on the correlation between variables. This method can improve the intra group correlation of variables, reduce the correlation between different groups, and use common factors to represent the indicators of different groups [14].

3.2. Data Collection

The data source of this study is second-hand data. By organizing the Sichuan Province Science and Technology Statistical Yearbook from 2012 to 2022, data on four major items of R&D investment, activity participation, scientific and technological achievements, and achievement benefits of

enterprises, as well as 18 sub items including funding investment, number of scientific research personnel, and patent output, were obtained.

3.3. Index Screening based on Principal Component Analysis

3.3.1. Data Check

This article analyzed the validity of the scale using SPSS 24.0KMO and Bartlett's test. The results showed that the KMO value of the scale was 0.626, and the result was significant ($p<0.001$), indicating that the results are suitable for factor analysis and the correlation between variables is significant, indicating good validity of the scale.

3.3.2. Principal Component Contribution Rate

This study used principal component analysis to extract principal components with initial eigenvalues greater than 1, as shown in the table below. The total variance explanation table shows that there are a total of 7 principal components with initial eigenvalues greater than 1, and the cumulative variance of the 7 principal components indicates that they can explain 85.25% of the variable's information and have high substitutability.

Table 2. Principal component contribution rate of the sca

Explanation of Total Variance									
component	initial eigenvalue			Extract the sum of squared loads			Sum of squared rotational loads		
	total	Variance percentage	Accumulated%	total	Variance percentage	Accumulated%	total	Variance percentage	Accumulated%
1	5.163	28.681	28.681	5.163	28.681	28.681	3.339	18.551	18.551
2	2.852	15.847	44.528	2.852	15.847	44.528	3.199	17.773	36.324
3	2.326	12.920	57.447	2.326	12.920	57.447	2.567	14.259	50.583
4	1.571	8.729	66.176	1.571	8.729	66.176	1.802	10.011	60.594
5	1.278	7.098	73.274	1.278	7.098	73.274	1.802	10.009	70.602
6	1.100	6.110	79.384	1.100	6.110	79.384	1.526	8.476	79.079
7	1.056	5.865	85.249	1.056	5.865	85.249	1.111	6.171	85.249
8	.629	3.494	88.744						
9	.427	2.370	91.114						
10	.368	2.046	93.160						
11	.264	1.466	94.626						
12	.245	1.362	95.988						
13	.210	1.168	97.156						
14	.181	1.003	98.159						
15	.163	.907	99.066						
16	.140	.775	99.841						
17	.024	.134	99.975						
18	.004	.025	100.000						
Extraction method: Principal Component Analysis.									

3.3.3. Factor Analysis

To more directly analyze the relationship between various factors, this article uses the rotated component matrix in factor analysis to distinguish the relationship between principal components [15]. As shown in the table, a total of seven principal components with eigenvalues greater than 1 were extracted, among which the enterprise activity participation index constructed in the article partially overlaps with R&D investment and scientific and technological achievements. Obviously, the factors extracted have similarities, overlaps, and differences with the dimensions extracted in this article. The reason for the difference is that the selection of quantitative indicators tends to be more focused on the quantification of indicators, while the dominant position of enterprises in industry university research collaborative innovation is mainly reflected in the role of enterprises at different stages of the process. Firstly, in the process of industry university research collaborative innovation with enterprises as the main body, the R&D investment of enterprises includes capital investment and R&D personnel investment. The process and role of R&D personnel and project participants in industry university research collaborative innovation are not the same. The main difference is that R&D personnel mainly engage in technology research and innovation, while the role of project participants includes not only technology research and development, but also market development, technology services, etc. Therefore, they should be distinguished [16]. Secondly, the dominant position of enterprises in industry university research collaborative innovation is also reflected in the process of activity participation, including the number of industry university research participants and the number of personnel involved in industry university research collaborative innovation activities. The number of industry university research collaborative innovation systems initiated and constructed by enterprises, as well as the number of rights and ownership of cooperative achievements belonging to enterprises, are respectively in the process of activity participation and the process of scientific and technological achievement formation and transformation. Therefore, based on the process perspective of industry university research collaborative innovation, they should be separated. Again, in the industry university research collaborative innovation system with enterprises as the main body, enterprises must become the main body in forming scientific and technological achievements and their transformation, thereby promoting the industrial application of scientific and technological achievements. Finally, enterprises should become the main beneficiaries in the process of collaborative innovation between industry, academia, and research. The application of scientific and technological achievements can promote the marketization of technology, form the core advantages of enterprises, and ultimately bring huge benefits to enterprises. These benefits ultimately promote the development and growth of enterprises. Therefore, in the enterprise led collaborative innovation system of industry university research, enterprises must become the main body of research and development investment, activity participation, scientific

and technological achievements, and achievement benefits.

Table 3. Factor Analysis - Rotating Component Matrix Table

Rotated component matrix							
	1	2	3	4	5	6	7
X11The proportion of industry university research and development funds invested by enterprises to the total research and development funds							.917*
X12The intensity of R&D investment in enterprises		.				.971*	
X13The number of industry university research and development personnel invested by enterprises		.820*					
X14The number of industry university research and development teams invested by enterprises		.862*					
X15Growth rate of research and development personnel in industry, academia, and research					.652*		
X21The number of industry university research collaborative innovation systems initiated by enterprises	.923*						
X22The number of industry university research collaborative innovation systems constructed by enterprises	.649*			.	.	.717*	.
X23The number of teams participating in collaborative innovation between industry, academia, and research by enterprises		.788*					
X24The number of personnel involved in collaborative innovation between industry, academia, and research in enterprises		.804*					
X31The number of intellectual property indicators such as papers, patents, and monographs completed by enterprises as the main body of intellectual property rights		.		.882*			
X32The subject of achievement transformation - the number of intellectual property ownership rights such as papers, patents, monographs, etc. that have been transformed by the enterprise				.870*			
X33The number of project achievements applied in the next five years					.751*		
X34Number of authorized patents/number of R&D personnel					.836*	-	
X35The number of cooperative achievements whose usage rights belong to the enterprise	.947*				.		
X36The number of cooperative achievements with ownership belonging to the enterprise	.930*						
X41Benefit from Achievements - The degree of technological innovation in key project outcomes			.899*				
X42Achievement Benefit - Maturity of Industrialization Application Prospects for Project Achievements			.931*				
X43Benefit from achievements - the degree to which collaborative innovation projects demonstrate and drive the development of related industries			.894*				
Reliability value	.673	.873	.903	.862	.585	.761	
Extraction method: Principal Component Analysis. Rotation method: Caesar normalization maximum variance method. a. The rotation has converged after 7 iterations.							

3.3.4. Comprehensive Score and Ranking

The score coefficient matrix corresponding to the three principal components calculated by SPSS is used to obtain the expressions of the four principal components, and further calculate the score of the enterprise led position as the main body of industry university research collaborative innovation.

F=(5.163F1+2.585F2+2.326F3+1.571F4+1.278F5+1.100F6+1.056F7)/15.346)

4. Conclusion and Discussion

4.1. Research Conclusion and Implications

The collaborative innovation and sharing of industry university research is a complex system engineering. This article designs scales and survey questionnaires, and verifies the evaluation system of the dominant position of enterprises in industry university research collaborative innovation through principal component analysis and factor analysis based on the obtained survey data. In the industry university research collaborative innovation system, the main role of enterprises is reflected in four aspects: R&D investment, activity participation, scientific and technological achievements, and achievement benefits. Based on these four aspects, an evaluation system for the dominant position of enterprises is constructed. In the industry university research collaborative innovation, the evaluation system for the dominant position of enterprises is crucial. The research conclusions of this system are of great significance for promoting the development of industry university research collaborative innovation. Enterprises play a leading role in collaborative innovation, so the establishment and optimization of the evaluation system are crucial for promoting innovation and improving efficiency.

Firstly, through research, it is known that enterprises play a dominant role in collaborative innovation. Establishing an evaluation system for the subject status of industry university research collaborative innovation can highlight the dominant position of enterprises in industry university research collaborative innovation, including their roles in project decision-making, resource investment, technological innovation, etc. This helps to clarify the responsibilities and roles of enterprises in collaborative innovation, thereby promoting the in-depth development of collaborative innovation.

Secondly, the establishment of an evaluation system can enable innovation entities to have a deeper understanding of their collaborative relationships and conduct reasonable evaluations. The evaluation system may focus on the collaborative relationships between enterprises, academic institutions, and research institutions, including the depth, frequency, and results of cooperation, which helps to evaluate

the closeness of the collaborative relationships and provide guidance for future cooperation.

Table 4. Component score matrix

Component score coefficient matrix							
	1	2	3	4	5	6	7
X11The proportion of industry university research and development funds invested by enterprises to the total research and development funds	-.036	-.056	.012	.009	.047	.058	.830
X12The intensity of R&D investment in enterprises	-.109	.013	.007	-.013	.012	.674	.038
X13The number of industry university research and development personnel invested by enterprises	.046	.276	-.009	-.055	-.107	-.024	.075
X14The number of industry university research and development teams invested by enterprises	-.081	.351	.024	-.169	.053	.038	-.145
X15Growth rate of research and development personnel in industry, academia, and research	-.041	-.172	-.020	.001	.444	.156	-.338
X21The number of industry university research collaborative innovation systems initiated by enterprises	.315	-.065	-.008	-.048	-.008	-.039	.001
X22The number of industry university research collaborative innovation systems constructed by enterprises	.137	-.013	.008	-.037	.034	.434	.012
X23The number of teams participating in collaborative innovation between industry, academia, and research by enterprises	-.103	.288	.015	-.038	.039	.053	-.173
X24The number of personnel involved in collaborative innovation between industry, academia, and research in enterprises	.020	.274	.029	-.076	-.015	-.036	.120
X31The number of intellectual property indicators such as papers, patents, and monographs completed by enterprises as the main body of intellectual property rights	-.072	-.105	-.031	.604	-.048	.018	.011
X32The subject of achievement transformation - the quantity of intellectual property ownership such as papers, patents, monographs, etc. transformed by enterprises	-.044	-.123	-.014	.598	-.043	-.038	-.035
X33The number of project achievements applied in the next five years	.000	.028	-.011	.040	.398	-.021	.081
X34Number of authorized patents/number of R&D personnel	-.001	.039	-.056	-.110	.484	-.029	.130
X35The number of cooperative achievements whose usage rights belong to the enterprise	.323	-.032	-.024	-.042	-.009	-.093	-.035
X36The number of cooperative achievements with ownership belonging to the enterprise	.325	-.033	-.056	-.043	-.012	-.104	-.058
X41Benefit from Achievements - The degree of technological innovation in key project outcomes	-.015	.066	.373	-.082	-.065	-.045	.020
X42Achievement Benefit - Maturity of Industrialization Application Prospects for Project Achievements	-.036	.012	.380	-.031	-.034	.037	.006
X43Benefit from achievements - the degree to which collaborative innovation projects demonstrate and drive the development of related industries	-.046	-.007	.361	.040	-.039	.031	.016
Extraction method: Principal Component Analysis. Rotation method: Caesar normalization maximum variance method.							

Finally, the evaluation system focuses on the risk-taking and profit distribution of enterprises in collaborative innovation, as well as relevant policy support and guarantees, which helps balance the interests of all parties and promote more enterprises to participate in collaborative innovation. At the same time, the research conclusions of the evaluation system may provide suggestions for policy formulation, including policy recommendations on incentivizing enterprises to participate in collaborative innovation, optimizing resource allocation, and strengthening intellectual property protection.

4.2. Research Shortcomings and Prospects

There may be some shortcomings in the research on the evaluation system of the subject status of enterprise led industry university research collaborative innovation. Firstly, due to the collaboration of multiple entities involved in industry university research collaborative innovation, there may be differences between different regions, industries, or organizations. Therefore, the evaluation system may lack consistency and standardization, which requires in-depth research on the evaluation system. Secondly, the evaluation system requires the collection and analysis of a large amount of data, including relevant information from enterprises, academic institutions, and research institutions. In the future, more data can be collected to further enrich the evaluation system. Thirdly, collaborative innovation between industry, academia, and research is a long-term process, and its effects and contributions may take some time to manifest. The evaluation system can consider evaluating the long-term effects of industry university research collaborative innovation to understand its long-term impact on economic development, social progress, and innovation capacity enhancement.

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