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Research on the Comprehensive Evaluation of Scientific and Technological Innovation Ability of Colleges and Universities Based on Prospect Theory

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Abstract

This study aims to construct a comprehensive evaluation system for scientific and technological innovation in universities. Through an in-depth analysis of university performance in areas such as scientific research projects, patent applications, and technology transfer, and considering the psychological behavioral characteristics of decision-makers, a new evaluation method has been proposed. This method not only takes into account the objective achievements of universities but also fully considers the subjective expectations and preferences of decision-makers, making the evaluation results more in line with the actual decision-making process. Empirical research has verified the effectiveness and reliability of the evaluation system, providing a scientific basis for the policy formulation and resource allocation of university scientific and technological innovation.

Keywords

Prospect Theory; University Science and Technology Innovation; Comprehensive Evaluation; Analytic Hierarchy Process.

1. Introduction

In the backdrop of globalization and the knowledge economy, the scientific and technological innovation capacity of universities has become an essential indicator of their overall strength and social service capabilities. As key players in scientific and technological innovation, the strength of a university's scientific and technological innovation directly impacts the overall effectiveness of the national innovation system and the driving force for regional economic growth. Therefore, a comprehensive, objective, and scientific evaluation of university technological innovation capability is of great significance for guiding university technological innovation work, optimizing resource allocation, and enhancing innovative ability. The prospect theory provides the theoretical framework for this study, revealing how people balance potential gains and losses when making choices. In the evaluation of university technological innovation capacity, decision-makers (such as policymakers and university administrators) often assess the value of different innovation activities based on their personal expectations and preferences. For instance, certain innovation projects may have characteristics of high risk and high return, and the risk attitudes of decision-makers will directly affect their assessment and support for these projects. This study first identifies the key indicators for evaluating university technological innovation capacity, which include but are not limited to research funding inputs, the number of research papers published, patent applications and grants, technological transfer and commercialization results, etc. It then collects data through expert interviews and quantitatively assesses these indicators. Based on the analysis above, this study proposes a comprehensive evaluation model that can not only assess the current level of technological innovation in universities but also predict their future development potential.

The significance of this study lies in providing universities with a new tool for self-assessment, helping them identify their strengths and weaknesses in technological innovation. At the same time, policy makers and higher education managers can utilize the findings of this study to optimize resource allocation, develop more effective technological innovation policies and incentive mechanisms, and thereby promote the innovative development of the entire higher education system.

2. Influencing Factors of Comprehensive Evaluation of Scientific and Technological Innovation Ability of Colleges and Universities

2.1. Allocation of scientific research resources

The allocation of research resources is the material basis for university technological innovation, which directly affects the scale and quality of research activities. A university with ample and high-quality research resources, such as advanced laboratories, rich bibliographic data, and excellent research teams, will find it easier to conduct research activities and attract more high-level research projects, resulting in more valuable research outcomes. At the same time, universities need to continuously optimize the allocation of research resources, improve resource utilization efficiency, and ensure that research resources are fully utilized for their intended purpose.

2.2. Scientific research output and translation efficiency

The output and transformation efficiency of research are core indicators for assessing the innovative capacity of universities. Research output primarily refers to published academic papers, applied patents, and awards received, while transformation efficiency refers to the process of translating theoretical research into practical applications. A university's technological innovation capability is fully demonstrated when it can produce a large number of high-quality research results in a short period and successfully apply them to actual production and life. In addition, universities need to strengthen the management and protection of research results, establishing a complete intellectual property management system, to promote the sustainable development of research results.

2.3. Scientific research management system

The optimization of the research management system is crucial for enhancing the technological innovation capability of universities. A scientific, efficient research management system can ensure the orderly conduct of research activities, reduce unnecessary administrative barriers, and provide a good working environment for researchers. Additionally, the research management system should possess flexibility and adaptability, which can be adjusted and improved based on the actual needs of research work. Universities should also establish a comprehensive research evaluation mechanism to encourage researchers to actively engage in innovative research, while strengthening the construction of research integrity to prevent the occurrence of unethical academic behaviors.

2.4. Industry-university-research cooperation network

The construction of a university-industry cooperation network is a bridge that connects universities with the industrial sector. Through close collaboration with businesses and

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research institutions, universities can timely understand market needs and technological trends, which provide strong support for the selection of research directions. At the same time, university-industry cooperation can also provide students with practical platforms to help them translate theoretical knowledge into practical abilities, cultivate their innovative spirits and entrepreneurial awareness. Universities can also introduce technological resources and talents from enterprises through university-industry cooperation, jointly develop research projects, and achieve resource sharing and mutual benefit.

2.5. Adaptability of the policy environment

The adaptability of the policy environment is also an important factor affecting the technological innovation capability of universities. Government measures such as technology policies, financial support, and tax incentives have a direct impact on university research activities. Therefore, universities need to closely follow changes in the policy environment, timely adjust their development strategies, make full use of policy advantages, and create favorable external conditions for research work. At the same time, universities should actively participate in the policy-making process, providing scientific bases for government decisions, and promoting the formation of a policy environment conducive to technological innovation in universities.

Comprehensive evaluation of university technological innovation capacity is a complex task that requires consideration from multiple angles. Only by fully considering and striving to improve research resource allocation, research output and transformation, research management systems, industry-university-research cooperation networks, and policy adaptability can universities maintain a leading position in fierce competition and make greater contributions to national technological advancement and economic social development. At the same time, universities need to continuously explore and innovate technological innovation models, strengthen international cooperation and exchanges, enhance their global influence, and make even greater contributions to social progress. In summary, the comprehensive evaluation system for university technological innovation capability includes the impact factors mentioned above, which are considered jointly when selecting universities based on technological innovation level and other relevant areas. As shown in table 1.

Table 1. Comprehensive evaluation factors of scientific and technological innovation ability of colleges and universities

Level 1 indicators	Secondary indicators
Allocation of scientific research resources A_1	Research Funding A_{11}
	Human Resources A_{12}
	Course Facility A_{13}
Scientific research output and translation A_2	Academic Achievement A_{21}
	Patent Activity A_{22}
	Transformation Result A_{23}
	Transform body A_{24}
Scientific research management system A_3	Institutional Design A_{31}
	Incentive Mechanism A_{32}
	Quality Control A_{33}
Industry-university-research cooperation network A_4	School-enterprise cooperation A_{41}
	Technology Transfer A_{42}
	Return on Investment A_{43}
Adaptability to the policy environment A_5	Policy Response A_{51}
	Policy support for A_{52}
	Ask for wizard A_{53}

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3. Comprehensive Evaluation of Scientific and Technological Innovation Capabilities of Colleges and Universities

This study constructs a new comprehensive evaluation model for university technological innovation capability based on prospect theory. The model integrates quantitative data and subjective judgment, considers the preferences and uncertainties of decision-makers, and evaluates multiple aspects of university research output, innovation capability, talent cultivation, etc. Through empirical analysis, we find that the model can provide more accurate and comprehensive evaluation results, helping universities identify their advantages and shortcomings, and optimize their technology innovation strategies. This research not only enriches the theoretical system of university technological innovation capability evaluation but also provides practical guidance for university technology innovation management.

The C-OWA operator combines sorting and weighting methods to achieve scientific weighting of evaluation indicator data. During the process of determining weights, C-OWA considers both the importance attached by decision-makers to different positions of evaluation indicators and the impact of subjective factors on weights. By ranking the evaluation indicators based on their importance and assigning weights based on their position in the ranking, C-OWA effectively balances subjective judgment with objective data, reducing the likelihood of extreme weight allocations caused by subjective factors and enhancing the objectivity and reliability of decision-making results.

3.1. Metric weighting based on the C-OWA operator

Firstly, we need to determine the relative position of each data item within the overall dataset A by performing a sort on the original data set $A_i = \{ x_1, x_2, ..., x_n \}$ .The purpose of sorting is to arrange data in descending order based on their magnitude, resulting in a new, sorted data set: $b_i = \{ b_0, b_1, ..., b_{n-1} \}$, where b_0 is the largest data and $b_{n-1}$is the smallest.

This step prepares for the subsequent weight assignment, because in C-OWA, the position of the data will directly affect its weights.

Next, we use the number of combinations to design the weights of the data b_i. In C-OWA, the calculation of weights is based on concepts in combinatorics, specifically the inverse of combinatorial numbers. The allocation of weights depends on the position of data after sorting, as well as the decision-maker's preference for these positions. Weights ω_{i+1} can be calculated using the following formula:

$$\omega_{i+1} = C_{n-1}^{i} / \sum_{k=0}^{n-1} C_{n-1}^{k} = C_{n-1}^{i} / 2^{n-1} \tag{1}$$

Among them, C(n-1,i) is the number of combinations of choosing i objects from n-1 objects, and C(n,n) is the full permutation number of n objects, which is equal to n!.

To calculate the absolute weight value ω_j for each indicator A_j, you first need to determine the weights ω_{i+1} for each data item, and then apply these weights to the corresponding data items b_i. The specific steps are as follows:

The decision data is weighted using the weight ω_{i+1}. This step involves multiplying each data item, bi, by its corresponding weight, ω_{i+1}, and then adding all the products together. The formula is as follows:

$$\bar{\omega}_j = \sum_{i=0}^{n-1} \omega_{i+1} b_i, j = 1,2,\cdots,m \tag{2}$$

The relative weight value ω_j'' of the metricA_j is calculated

$$\omega_j'' = \bar{\omega}_j / \sum_{j=1}^{m} \bar{\omega}_j , j = 1,2,\cdots,m \tag{3}$$

Where, m is the number of indicators, b_i is the ith data item in the sorted dataset, and j is the index of the indicator. The foreground value V(f) is given by:

$$V(f) = w(p_1) * v(x_1) + w(p_2) * v(x_2) + \ldots + w(pn) * v(xn) \tag{4}$$

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Where, p is the probability and x is the corresponding gain or loss value.

3.2. A comprehensive evaluation model of scientific and technological innovation ability of colleges and universities

The prospect theory was proposed by Kahneman and Tversky in 1979, which modified the traditional expected utility theory by emphasizing the non-rational decision-making behaviors of people when faced with uncertainty. The theory introduces the concepts of value function and probability weight function, as well as the reference point, to explain how people assess risks and benefits, and make economic decisions. The prospect theory is of great significance for understanding market behavior, risk management, and policy making.

Prospect theory proposes a formula for calculating the comprehensive prospect value :

$$V(f) = v(\Delta x)\pi(p) \tag{5}$$

Where, V(f) represents the overall value of the decision-making results; v(Δx) represents the value function's evaluation of the deviation of the decision outcome from the reference point (such as the initial state or the expected goal); π(p) represents the evaluation of the probability of a decision outcome by the probability weight function. With this formula, we can calculate the foreground value of any given decision outcome, which in turn predicts the individual's choice behavior.

4. Empirical Research and Discussion of Results

4.1. Evaluation process and evaluation results

4.1.1. Scored by experts

To optimize the allocation of technological innovation resources, four universities with outstanding performance are selected for comprehensive capability assessment. The assessment methodology integrates the 9-point scale and expert scoring, comprehensively evaluating the performance of universities in five dimensions: scientific resource configuration, scientific transformation and output, scientific management system, industry-university-research cooperation network, and adaptability to policy environments. The assessment results will provide decision support for the rational allocation of resources, and suggestions for improving the innovative capacity and efficient use of technological innovation resources of each university.

The language term set S, using the 9-point scale, includes: S = { s1(very weak), s2(weak), s3(somewhat strong), s4(strong), s5 (very strong), s6 (extremely strong), s7(powerful), s8(authoritative), s9(dominant)}.

In the comprehensive evaluation process of technological innovation resources allocation, multiple experts were invited to score the 20 tertiary indicators and obtain the original data. This data was then organized into a table and sorted from large to small to obtain the initial weight vector ω_j. This vector reflects the relative importance of each indicator within the overall evaluation system. As shown in Table 2:

Table 2. Expert scoring results.

Indicators	Expert assessment.					
	1	2	3	4	5	6
A_{11}	5.0	4.5	4.5	4.0	4.5	3.0
A_{12}	4.0	4.0	3.5	4.0	4.5	4.5
A_{13}	4.5	4.0	4.0	4.5	4.0	3.0
A_{21}	4.5	4.0	4.5	4.0	5.0	4.0
A_{22}	4.5	4.5	5.0	4.5	4.5	5.0

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A_{23}	4.5	5.0	5.0	4.0	5.0	5.0
A_{24}	3.5	4.0	4.5	5.0	4.5	5.0
A_{31}	3.5	4.0	4.0	4.0	5.0	4.0
A_{32}	4.0	3.5	3.0	4.5	4.0	4.0
A_{33}	4.0	4.0	4.5	4.0	5.0	5.0
A_{41}	4.5	3.0	4.5	4.0	4.5	4.5
A_{42}	4.5	4.5	4.0	4.5	4.0	4.5
A_{43}	3.5	4.0	3.0	4.5	4.5	4.0
A_{51}	4.0	4.0	4.5	4.0	5.0	4.0
A_{52}	4.0	4.5	4.0	4.0	3.5	4.5
A_{53}	3.5	3.0	4.0	4.0	5.0	5.0

4.1.2. Determination of indicator weights.

Next, using formula (1), we calculated the relative importance of each indicator and obtained a six-dimensional weighted vector ω_j. Then, through formula (2), we computed the absolute weights A_{ij} of all indicators. As shown in Table 3, we transformed the qualitative assessments of experts into quantifiable numbers.

Table 3. Indicator weights

Indicators	Weight	Indicators	Weight
A_{11}	0.050	A_{32}	0.048
A_{12}	0.048	A_{33}	0.046
A_{13}	0.047	A_{41}	0.051
A_{21}	0.051	A_{42}	0.047
A_{22}	0.057	A_{43}	0.046
A_{23}	0.059	A_{51}	0.051
A_{24}	0.049	A_{52}	0.049
A_{31}	0.047	A_{53}	0.044

After obtaining the absolute weights A_{ij}, through formula (3), the relative weights of each indicator are calculatedω_j''. The relative weights reflect the relative position and influence of each indicator within the entire evaluation system.

4.1.3. Expert Scoring Matrix

The experts rated the four indicators based on the scoring scale, resulting in the original matrix table 4. The assumption that experts are risk-neutral, denoted as "ξ=0.5," means that experts assess risks without bias towards either conservation or adventure.

Table 4. Experts score the original matrix

University	A21	A22	A23	A24
Y1	{S4，S6}	{S1，S3，S5}	{S4，S6，S7}	{S1，S2，S3}
Y2	{S2，S4，S6}	{S1，S4，S7}	{S2，S4，S6}	{S1，S2，S6}
Y3	{S4，S5，S6}	{S4，S6}	{S4，S6}	{S3，S5}
Y4	{S2，S3，S4}	{S3，S9}	{S1，S7}	{S2，S6}

Then, the original matrix was standardized to obtain the standardized matrix shown in Table 5. This step is to eliminate the impact of different scales between indicators, allowing for fair comparison of scores across different indicators.

Table 5. Normalization matrix

University	A_{21}	A_{22}	A_{23}	A_{24}
Y_1	$\{S_4, S_5, S_6\}$	$\{S_1, S_3, S_5\}$	$\{S_4, S_6, S_7\}$	$\{S_1, S_2, S_3\}$
Y_2	$\{S_2, S_4, S_6\}$	$\{S_1, S_4, S_7\}$	$\{S_2, S_4, S_6\}$	$\{S_1, S_2, S_6\}$
Y_3	$\{S_4, S_5, S_6\}$	$\{S_4, S_5, S_6\}$	$\{S_4, S_5, S_6\}$	$\{S_3, S_4, S_5\}$
Y_4	$\{S_2, S_3, S_4\}$	$\{S_3, S_6, S_9\}$	$\{S_1, S_4, S_7\}$	$\{S_1, S_3, S_5\}$

4.1.4. Calculate the foreground value

The foreground values are calculated by Eq. (5) and the results are shown in Table 6.

Table 6. The outlook of some indicators under each university

University	A_{21}	A_{22}	A_{23}	A_{24}
Y_1	0.149	0.097	-0.113	-0.495
Y_2	-0.162	-0.103	-0.064	-0.241
Y_3	0.127	0.148	0.184	0.038
Y_4	-0.424	-0.274	-0.242	0.139

In calculating the comprehensive forecast value, it is necessary to follow the same process for other tertiary indicators. As shown in Table 7, these computational results will provide the necessary data support for subsequent comprehensive assessments. Finally, calculate the comprehensive forecast values for each scheme and arrange them in Table 8, providing scientific and rational decision-making bases for decision-makers.

Table 7. Outlook values for all indicators by university

University	A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{24}	A_{31}
Y_1	0.231	-0.144	0.098	0.149	0.097	-0.113	-0.495	0.060
Y_2	0.131	-0.321	-0.684	-0.162	-0.103	-0.064	-0.241	0.183
Y_3	0.125	0.142	0.021	0.127	0.148	0.184	0.038	-0.201
Y_4	-0.481	0.273	0.228	-0.424	-0.274	-0.242	0.139	-0.461
University	A_{32}	A_{33}	A_{41}	A_{42}	A_{43}	A_{51}	A_{52}	A_{53}
Y_1	0.194	-0.472	-0.311	0.081	0.227	-0.201	-0.271	0.183
Y_2	-0.201	-0.482	0.185	0.151	-0.593	-0.273	-0.461	0.191
Y_3	-0.121	0.434	0.213	0.342	-0.123	0.281	0.233	-0.142
Y_4	-0.554	0.131	-0.283	-0.875	0.174	0.085	-0.691	0.183

Table 8. The overall outlook for each scenario

University	Y_1	Y_2	Y_3	Y_4
$\upsilon(Y_i)$	-0.035	-0.133	0.087	-0.151

The comprehensive prospects value ranking for each solution is asfollows:$\upsilon Y_3 > \upsilon Y_1 > \upsilon Y_2 > \upsilon Y_4$,Therefore, the third university has the highest technological innovation capability among all universities.

After calculating the optimal result through the prospect theory, we used the data from Table 6 to draw the area chart of evaluation indicators for each alternative supplier (Figure 2), and conducted further analysis on four suppliers.

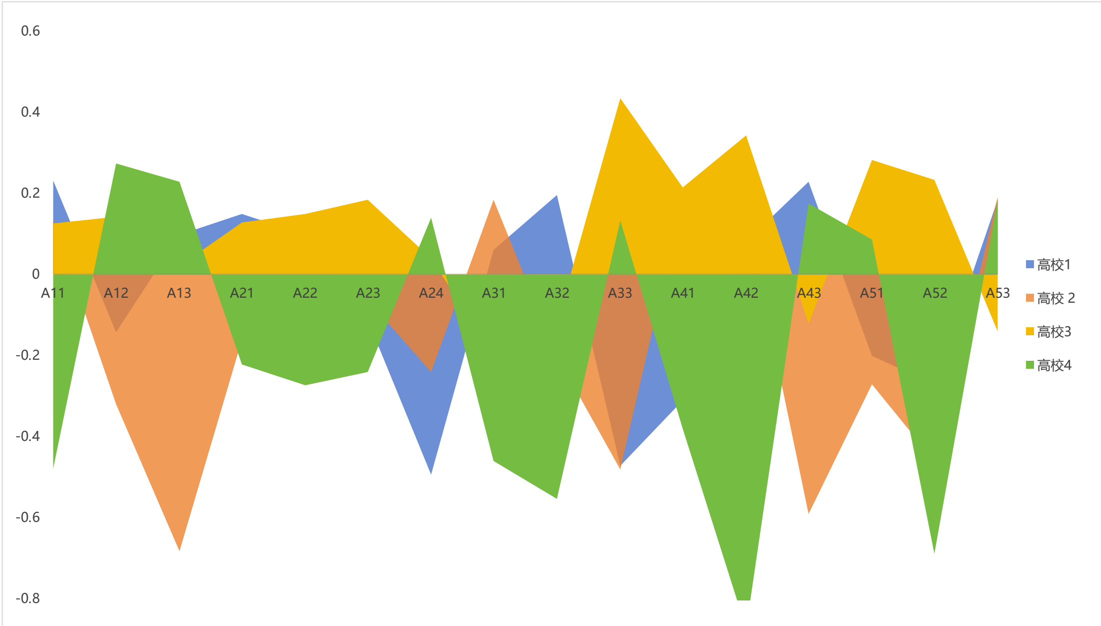

Figure 1. Area map of the prospect value of the evaluation of scientific and technological innovation ability of colleges and universities

4.2. Analysis of results

In the comprehensive evaluation system for university technological innovation capabilities, transformation resultA_{23}has the highest weight, as it is a direct reflection of the applied value of university research results and is also an important driving force for economic and social development.

The performance of universities in technological innovation can be assessed by considering multiple dimensions of data, including the volume of technology contracts, the number of patent translations, the revenue from technological services, as well as the application range, market share, and economic benefits generated by the results.

The percentage of patent activities A_{22} ranks second, which can be assessed by analyzing the data on patent applications, grants, quality (such as the number of citations), and layout (including international patent applications) from universities in recent years. In addition, the situation of implementing and commercializing patents should also be considered, such as assessing licensing, transferring, and technological cooperation.

Academic achievements A_{21}, School-enterprise cooperation A_{41}, Policy ResponsesA_{51}, Research funding A_{11} ranked in order. Academic achievements are one of the important indicators for assessing the research level and academic impact of universities. They can be demonstrated through the publication of high-quality academic papers and books, which showcase the outcomes and contributions of universities in both fundamental and applied research. University-enterprise cooperation is a significant way to integrate university technology innovation with industrial development. It involves engaging in collaborative research and technology transfer activities with businesses, which translates research findings into actual production while providing technological support and talent development for businesses. Policy responsiveness is an important aspect of universities aligning with national strategic needs and contributing to the national innovation-driven development strategy. This is achieved by developing plans and research directions that are congruent with national strategic needs, and by participating in the construction of national major technological projects and innovation platforms. Adequate research funding is essential to ensure the successful conduct of research activities by universities. It enables the attraction and cultivation of excellent research talents, as well as the development of high-level research projects and experimental studies.

5. Conclusion

The comprehensive evaluation study of university technological innovation capability based on prospect theory aims to build a scientific and comprehensive evaluation system. By analyzing multi-dimensional indicators such as research resource allocation, research output and transformation, research management system, industry-university-research cooperation network, and policy environmental adaptability, it assesses the overall technological innovation capability of universities and proposes targeted improvement suggestions to promote the continuous development of higher education. The evaluation method for university technological innovation capability based on prospect theory has significant advantages in terms of both scientific accuracy and practical applicability. It integrates the opinions of different decision-makers and considers their psychological factors, which not only enhances the accuracy and reliability of the evaluation but also increases people's acceptance and execution willingness. Additionally, this method provides strong theoretical support for governments and relevant departments to formulate university technological innovation policies, helping to optimize resource allocation and promote the sustainable development of university technological innovation.

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