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Evaluation Indicator Construction of Scientific and Technological Innovation Ability for Application-Oriented Universities

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Abstract: This paper constructs the evaluation indicator system of scientific and technology innovation ability for application-oriented universities with the principal component analysis and SPSS software. Moreover, the scientific and technology innovation ability of five applied-oriented universities are analyzed with the evaluation indicator system. Finally, the paper proposes suggestions on the education input, innovation input, technology transformation and innovation environment in order to improve the technological innovation ability and optimize the research decision.

1. Introduction

Application-oriented universities are local undergraduate universities for the training of applied technical talents. Such universities are different from traditional research-oriented colleges and higher vocational colleges, which are the in-depth reform of the training mode of modern higher education[1]. The significance is not only a great alleviation of the structural contradictions in the college graduates' employment, but also a technical talent reservation for the national economic transformation and upgrading. A powerful platform is provided for middle and junior college students and social member to continue their studies[2]. Moreover, the lack of effective teaching mode will gradually changed in most of local undergraduate colleges and universities. The disjunction between teaching and practice, the formalized university-enterprise cooperation and other problems may be even changed completely. These will help to improve the teaching quality of higher education and promote the diversified development of higher education[3]. In particular, it will gradually change the long-term thought of "emphasizing learning over art" in China, and help guide the whole society to respect for labor, technology and creation[4].

At present, foreign academic research on scientific and technological innovation ability mainly focus on the college evaluation and performance evaluation. The evaluation indicator system of scientific and technological innovation ability for application-oriented universities has become a hot spot in domestic academic research. Chen constructed the evaluation indicator of scientific and technological innovation ability for universities based on the analysis of the current situation of scientific and technological innovation ability of universities at home and abroad[5]. Xue established an evaluation system of scientific and technological innovation ability in universities, on the basis of analyzing the connotation and components of scientific and technological innovation ability[6]. Zhang designed the quantitative and comprehensive evaluation indicator system of scientific and technological innovation ability of universities[7]. Xiong summarized the common evaluation methods of scientific and technological innovation ability. From a comparable angle, the literature compared the evaluation method of scientific and technological innovation ability from both qualitative and quantitative aspects[8]. Li put forward the indicator system to evaluate the scientific and technological innovation in universities[9]. The research on scientific and technological innovation ability can promote the teaching and talent training, optimize the allocation of scientific and technological resources, improve the scientific and technological innovation ability of application-oriented universities. It also can continuously promote the development of scientific and technological innovation, and better serve the national economic and social[10]. On the other hand, the continuous research on the scientific and technological innovation ability of application-oriented universities, explore the nature and rule of the innovation ability, systematically summarize the experience of scientific and technological innovation, and provide an important basis for the government to formulate correct scientific and technological innovation policies[11].

These literature provide an important reference for the objective evaluation of science and technology innovation ability, from a certain angle or a range of evaluation. However, there are some problems about indicator selection, such as incomplete selection basis, insufficient indicators, excess subjective components, and too strong indicator correlation. These indicators cannot effectively reflect the science and technology innovation ability. This paper constructs an innovation ability evaluation model with the principal component analysis based on the data in the science and technology statistics compilation. According to the comprehensive score of the main components, this paper ranks 5 application-oriented universities of the scientific and technological innovation ability, and obtains the evaluation results of the innovation ability. Combined with the actual situation of scientific and technological innovation of application-oriented universities, this paper finally puts forward targeted suggestions and countermeasures.

2. The Construction of the Evaluation Indicator System

Table 1: Evaluation indicator system of scientific and technological innovation ability

The first level indicator	The second level indicator	The third level indicator
Comprehensive capacity of scientific and technological innovation	Foundation of scientific and technological innovation	X1 R&D (research and design) personnel
		X2 R&D activity personnel
		X3 Full-time equivalent of R&D personnel
	Input of scientific and technological innovation	X4 R&D input
		X5 Intramural expenditures on R&D
		X6 R&D projects
		X7 Input of Personnel in R&D projects
		X8 Input of funds in R&D projects
		X9 External Expenditure on R&D
	Output of scientific and technological innovation	X10 Publication on science and technology
		X11 Scientific papers issued
		X12 Appraisal results
		X13 Technology transfer contracts signed
		X14 Technology transfer revenue
		X15 Achievement awards

The evaluation of scientific and technological innovation ability contains many aspects, so it is a complex ability system. The evaluation of scientific and technological innovation should involve all the links of scientific and technological innovation activities in application-oriented universities[12].

According to the characteristics of each link of scientific and technological innovation, the evaluation should follow the principles of scientific, holistic, controllable and guiding[13]. Based on the characteristics and principles, the indicator system is built combined with evaluation indicator of science and technology innovation ability for universities from the Ministry of Education. This system can be divided into three levels, as shown in Table 1.

3. Comprehensive Evaluation of Scientific and Technological Innovation Ability

The innovation ability evaluation includes 15 variables. The relationships between these variables need to be analyzed and recombined. Then a small number of comprehensive variables are extracted. These variables are unrelated to each other, but contain the information of original related variables. A principal component analysis method is chosen to solve these problems. In this paper, 5 application-oriented universities are selected as sample data. The specific data are mainly derived from the Science and Technology Statistics of Universities in 2020, and SPSS software is used for principal component analysis.

As one of the multivariate statistical methods, principal component analysis method is to calculate the coefficient matrix of variable correlation. According to the composition information of the matrix, the method extracts a few variables to show the relationship between multiple variables. the random variables extracted are usually called the main component. Then, the variables are divided by comparing the correlation. The high correlation of variables are classified as the same, and the low correlation of variables are classified into different categories. A small number of unrelated variables were analyzed in multiple variables when information loss was avoided as much as possible. Meanwhile, the weights are determined by the contribution of variance. The final composite score is calculated further.

3.1. Principal Component Analysis

Table 2: Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.689	57.929	57.929	8.689	57.929	57.929
2	4.886	32.574	90.503	4.886	32.574	90.503
3	.955	6.367	96.870			
4	.469	3.130	100.000			
5	2.416E-15	1.611E-14	100.000			
6	6.256E-16	4.171E-15	100.000			
7	3.938E-16	2.625E-15	100.000			
8	2.463E-16	1.642E-15	100.000			
9	8.024E-17	5.349E-16	100.000			
10	-2.581E-17	-1.720E-16	100.000			
11	-8.855E-17	-5.903E-16	100.000			
12	-2.451E-16	-1.634E-15	100.000			
13	-3.467E-16	-2.311E-15	100.000			
14	-4.594E-16	-3.063E-15	100.000			
15	-7.799E-16	-5.199E-15	100.000			

KMO and Bartlett's test can determine whether the sample is suitable for principal component analysis. KMO test is used for the correlation and partial correlation between variables, and Bart1ett's spherical test is used to determine whether the correlation array is a unit array. According to SPSS software, the KMO statistic is 0.762 more than 0.7, and the results of Bartlett's spherical test show that the P-value is less than 0.05, so there is a strong correlation between variables. The data can be analyzed by the principal component analysis.

Based on the eigenvalues, variance contribution, and cumulative contribution of each component, only the first two eigenvalues are greater than 1 shown in Table 2. Therefore, only the first two components are extracted from the principal components. The variance of the first principal component accounted for 57.929% of all the variance of the principal components. The variance of the first two principal components contributed to 90.503% more than 85%. Thus, the first two principal components can describe the level of technological competitiveness. The 15 original variables can be compressed into two principal components, due to the high correlation between the original variables.

Variable communalities is the degree expressed by common factors that can extract the original information contained in each variable. Most variable common degree are more than 80% except for the External Expenditure on R&D, Publication on science and technology, appraisal result, technology transfer revenue as shown in Table 3. Therefore, the interpretation ability of the extracted two common factors is relatively strong.

Table 3: Communalities

Indicator	Initial	Extraction
R&D (research and design) personnel	1.000	.984
R&D activity personnel	1.000	.980
Full-time equivalent of R&D personnel	1.000	.985
R&D input	1.000	.967
Intramural expenditures on R&D	1.000	.904
R&D projects	1.000	.812
Input of personnel in R&D projects	1.000	.998
Input of funds in R&D projects	1.000	.978
External Expenditure on R&D	1.000	.735
Publication on science and technology	1.000	.770
Scientific papers issued	1.000	.955
Appraisal results	1.000	.785
Technology transfer contracts signed	1.000	.965
Technology transfer revenue	1.000	.761
Achievement awards	1.000	.995

Table 4: Component Matrix

Indicator	F1	F2
R&D (research and design) personnel	.974	-.189
R&D activity personnel	.975	-.175
Full-time equivalent of R&D personnel	.980	-.154
R&D input	.674	.716
Intramural expenditures on R&D	.731	.608
R&D projects	.901	.014
Input of personnel in R&D projects	.988	-.150
Input of funds in R&D projects	.461	.875
External Expenditure on R&D	.588	.623
Publication on science and technology	.718	-.504
Scientific papers issued	.953	-.217
Appraisal results	.023	-.886
Technology transfer contracts signed	-.338	.922
Technology transfer revenue	.052	.871
Achievement awards	.976	-.205

Table 4 shows the load matrix of initial factor, which shows the load degree of each factor and the influence degree of each factor. It can be seen that the first principal component (F1) is more than 0.9, including R&D personnel, activity personnel, full-time equivalent personnel, R&D projects, input of personnel in R&D projects, scientific papers issued and achievement awards. F1 reflects the total input of scientific and technological innovation, on behalf of the absolute competitiveness of input. The second principal component (F2) is more than 0.7, including R&D input,Input of funds in R&D projects, Technology transfer contracts signed and technology transfer revenue. F2 reflects the output efficiency of technological innovation, on behalf of the competitiveness of technological innovation output.

3.2. Establish Comprehensive Model

The eigenvalues of the principal components and the contribution rate of cumulative variance, and the principal component variance are shown in Table 5. From Table 2, the characteristic values of the first and second principal components are 8.689 and 4.886 respectively. The cumulative contribution rate is 90.503% more than 80%, which contains the majority of the original data. Therefore, the first two principal components can replace the original 15 indicators, recorded as F1 and F2. The scientific and technological innovation ability of five applied universities are evaluated to obtain linear combination model of principal component score function.

$$F1=0.112zX1+0.112zX2+0.113zX3+0.078zX4+0.084zX5+0.0104zX6+0.114zX7+0.053zX8+0.068zX9+0.083zX10+0.110zX11+0.003zX12-0.039zX13+0.006zX14+0.112zX15$$

$$F2=-0.039zX1-0.036X2-0.032zX3+0.147zX4+0.124zX5+0.003zX6-0.031zX7+0.179zX8+0.128zX9-0.103zX10-0.044zX11-0.181zX12+0.189zX13+0.178zX14-0.042zX15$$

Table 5: Component Score Coefficient Matrix

Indicators	Component	
	1	2
R&D (research and design) personnel	.112	-.039
R&D activity personnel	.112	-.036
Full-time equivalent of R&D personnel	.113	-.032
R&D input	.078	.147
Intramural expenditures on R&D	.084	.124
R&D projects	.104	.003
Input of personnel in R&D projects	.114	-.031
Input of funds in R&D projects	.053	.179
External Expenditure on R&D	.068	.128
Publication on science and technology	.083	-.103
Scientific papers issued	.110	-.044
Appraisal results	.003	-.181
Technology transfer contracts signed	-.039	.189
Technology transfer revenue	.006	.178
Achievement awards	.112	-.042

The representation of the principal component mainly is obtained from the meaning of several original indicators of large absolute coefficients in the linear combination, From Table 5, some indicator of the load coefficient is large in the first main component including R&D personnel, R&D activity personnel and full-time equivalent of R&D personnel. It reflects the basic situation of scientific and technological innovation in application-oriented universities, called the main component of the innovation foundation. Some indicator of the load coefficient is relatively large in the second main component including R&D input, Intramural expenditures on R&D, input of funds in R&D projects, external Expenditure on R&D, technology transfer contracts signed, technology transfer revenue. It reflects the investment in scientific and technological innovation in application-oriented universities, called the main component of innovation input.

After selecting the principal components, the scores of the two principal components can be calculated. The weight is the proportion of the variance contribution rate of the two principal components in the cumulative variance contribution rate. The comprehensive score (F) is weighted aggregate, such as F=0.6400F1+0.3599F2. The calculation results are shown in Table 6.

Table 6: Comprehensive ranking of indicators

University	F1	F2	F
U1	1.78332	-.12333	1.10
U2	-.31453	1.33497	.28
U3	-.46948	.58217	-.09
U4	-.47607	-.53995	-.50
U5	-.52325	-1.25386	-.79

The rank of five application-oriented universities of scientific and technological innovation ability is calculated from the comprehensive score, U1> U2> U3> U4> U5. It can be seen from Table 6 that U1 have the highest comprehensive score, U2 are positive scores, U3, U4 and U5 scores are negative. Among thee influencing factors, the most important influencing factor is the first main component. Therefore, the application-oriented universities need to improve their own scientific and technological innovation ability and innovation level. They need to increase input of each related factor in the first main component.

4. Conclusions and Strategy Recommendations

Based on the analysis results and the science and technology innovation theory, this paper proposes some suggestions on the improvement of scientific and technological innovation and competitiveness from two main components.

Firstly, the government should increase the investment in the infrastructure construction of scientific and technological innovation for application-oriented universities and optimize the environment for education and scientific research. According to the first main components, it can be seen that the load coefficient is large such as R&D personnel, R&D activity personnel and full-time equivalent of R&D personnel. It reflects the basic situation of scientific and technological innovation of application-oriented universities. The large load coefficient of applied-oriented universities has strong scientific and technological innovation ability.

Secondly, the input in education should be increased and the management system for scientific and technological innovation funds should be improved. In the second main component, the load coefficient is relatively large such as R&D input, Intramural expenditures on R&D, input of funds in R&D projects, external Expenditure on R&D, technology transfer contracts signed, technology transfer revenue. It reflects the situation of science and technology innovation input in application-oriented universities, called the main component of innovation input. The growth of scientific and technological innovation ability has a positive relationship with the amount of input. Therefore, the government input on education scientific research should be increased. The allocation of funds should be adjusted for a relatively reasonable proportion of used for equipment purchase and infrastructure construction and human capital expenses for scientific research and education management. The fundamental driving force of scientific and technological innovation ability is the collaborative development of human thinking, concentration and management environment.

Thirdly, the cooperation mechanism between application-oriented universities and enterprises should be improved to achieve mutual win-win situation. The effective docking should be strengthened between the scientific and technological innovation activities of application-orientated universities and the frontier issues of enterprise development. In that case, the application-orientated universities can improve innovation ability in solving the problem of enterprise, moreover, enterprises can improving competitiveness and efficiency in the introduction of applied university intelligence resources. R&D advantages of application-oriented universities should combine with the production and marketing advantages of enterprises. That can promote the establishment of industry-university-research cooperation between enterprises and application-oriented universities. The win-win development realization can promote technological innovation in the society and promote the improvement of the scientific and technological innovation ability of application-oriented universities.

Fourthly, the evaluation system of scientific and technological innovation should be improved. The innovation incentive mechanism of application-oriented universities should also be improved. A suitable scientific research environment should be created. R&D personnel of application-oriented universities have a significant influence on the innovation ability. Therefore, it is necessary to improve the talent evaluation mechanism, stabilize the innovative talent team, establish a long-term scientific research mechanism. That will promote orderly scientific activities, stable and efficient environment of scientific research, the comprehensive improvement of the scientific and technological innovation ability of application-oriented universities.

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References

[1] Wang S. G. (2020) Exploration of science and technology Practice and Innovation ability Cultivation Mode in Application-oriented Universities. Science and Technology Management Research, 40 (8).

[2] Jing Y.R. (2021) Research on improving the strategy of scientific and technological Innovation and Entrepreneurship Ability of college Students in local Application-oriented Universities. Science and technology economic market, 7.

[3] Hao Y. J. (2017) The Cultivation of Innovation and Entrepreneurship Ability: takeing Hebei Normal University of Science and Technology as an example. Modernization of Education, 4.

[4] Xiao R. H. (2018) Research on the Transformation Path of Scientific and Technological Achievements in "Government-University-Enterprise" Collaborative Innovation and Application-oriented Universities. Heilongjiang Higher Education Research, 36 (11).

[5] Chen G. F., Jiang Q. Q., Tang Y. Z. (2021) Evaluation on Scientific and Technological Innovation Ability of Universities under the background of world-class Universities with Chinese Characteristics. Scientific and technological Progress and Countermeasures, 10.

[6] Xue W. T. (2021) Research on scientific and technological Innovation Ability Evaluation based on ecological niche theory. North University of China.

[7] Zhang J. T., Wang G. J., Wu J. etc. (2018) Research on Scientific and Technological Innovation Ability Evaluation of Jiangsu Universities Based on Entropy Right-DEMATEL. Science and Technology Management Research, 38 (09).

[8] Xiong L. L. (2018) Dynamic Comprehensive Evaluation of Scientific and Technological Innovation Ability in Chinese Universities. Nanchang University.

[9] Li C. L, Liu L. L. (2018) Evaluation of science and Technology Innovation Ability of Undergraduate Universities in Hebei Province (based on the analysis of science and technology statistical data of universities from 2012 to 2016). Science and Technology Management Research, 38 (02).

[10] Huang C. B. (2017) Research on the Evaluation of Scientific and Technological Innovation Ability in Universities from the innovation-driven perspective. Scientific and technological Innovation and Application, 34.

[11] Wang J. G., Zhang Z. Q., Wang J. (2017) Evaluation of Scientific and Technological Innovation Ability of Universities in Beijing. Scientific and technological Progress and Countermeasures, 34 (20).

[12] Cheng H. (2017) Evaluation and evolution of scientific and technological Innovation Ability in provincial Universities. Dalian University of Technology.
[13] Bai Y, Zheng T. T., Liu H., Zhao X. C. (2017) Construction of Scientific and Technology Innovation Ability Evaluation Model Based on Rooted Theory. Science and Technology Management Research, 37 (05).