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ARTICLE

Design Index and Empirical Analysis of the Evaluation Index System for the Transformation of Scientific and Technological Achievements of Universities in Beijing, Tianjin and Hebei

Guoru Yang* Yuenan Xu

School of Public Administration, Hebei University of Economics and Business, Shijiazhuang, Hebei, 050061, China

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ABSTRACT

Promoting the transformation of scientific and technological achievements of universities and colleges in Beijing, Tianjin, and Hebei is an important measure to enhance the level of scientific and technological development in universities, enhance the scientific and technological synergy of Beijing-Tianjin-Hebei urban agglomeration, practice the coordinated development strategy of Beijing, Tianjin and Hebei, and promote the construction of Xiong'an New District. Based on the scientific and technological input of colleges and universities, the development of science and technology and the output of science and technology, this paper uses Delphi and AHP to construct a Beijing, Tianjin, Hebei University Science and Technology Achievement Transformation Performance Evaluation System from the perspectives of transformation potentials, scientific research activities and achievements transformation of university scientific and technological achievements. An empirical analysis was carried out to provide reference for the government's efficient decision-making and improvement of strategies for transforming scientific and technological achievements in universities.

1. Introduction

The level of science and technology transformation in universities is an important factor in measuring the level of regional science and technology transformation. It is of strategic significance to promote the sharing of regional science and technology resources, improve the efficiency of resource allocation, and enhance regional scientific and technological innovation capabilities. The government attaches great importance to this. In 2015, the "Comprehensive Development Plan of Tianjin and Hebei" puts forward: "Bearing Beijing as an original technology headquarters, patent trading market, high-end innovation service centers, and talent distribution centers; Tianjin will be built as a demonstration of innovation and entrepreneurship for small and medium-sized technology companies, parks and modern manufacturing bases; and Hebei focuses on the promotion of high-tech products and services to form innovative pilot areas and entrepreneurship incubators. Following the revision of the "Promotion

**Corresponding Author:*
Guoru Yang
School of Public Administration, Hebei University of Economics and Business,
No. 47 *Xuefu Road, Shijiazhuang, Hebei,* 050061*, China.*
*E-mail: ygrwyyx@*163*.com.*

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of Scientific and Technological Achievements Conversion Law" in 2015, the State Council has successively promulgated the "Some Regulations for the Promotion of the Transformation of Scientific and Technological Achievements" and the "Action Plan for Promoting the Transfer and Conversion of Scientific and Technological Achievements." It is regarded as promoting the transformation of scientific and technological achievements in institutions of higher learning. The state has adopted policies and encouragement measures to standardize and guide the transformation of scientific and technological achievements. It has continuously increased the environmental support for the transformation of universities and colleges, emphasized the importance of transformation of scientific and technological achievements in universities, and demonstrated the important position of universities as a process of transforming scientific and technological achievements. The integration of talent cultivation, scientific research, and service to the society is one of the three major functions of colleges and universities. Promoting the transformation of scientific and technological achievements in universities and colleges in Beijing, Tianjin, and Hebei is a concrete manifestation of the social functions of the universities in the three places. It is an important driving force for promoting the coordinated development of Beijing, Tianjin, and Hebei. The current transformation of scientific and technological achievements has made continuous progress, but in this process there have also emerged a series of problems such as low efficiency in the transformation of scientific and technological achievements in universities and low levels of technology transactions and absorption. This paper evaluates the performance of transformation of scientific and technological achievements in Beijing-Tianjin-Hebei universities, aiming to provide reference for the government's efficient decision-making and strategies for improving the transformation of scientific and technological achievements in universities.

2. Research Status

Scholars engaged in the evaluation of scientific and technological achievements in the evaluation of research and application of scientific and technological achievements in colleges and universities have made a large number of attempts, but also made more research results.

Some scholars evaluated the status quo of the transformation of scientific and technological achievements in colleges and universities by establishing index systems or models. Wei Liu and Aiju Chen (2008) established an evaluation system for the transformation of scientific and technological achievements in colleges and universities based on the network-level analysis method, which includes scientific and technological innovation capabilities, scientific and technological achievements transformation capabilities, scientific and technological research and development capabilities, and transformed environmental performance.[1] Huiyong Song (2014) used data envelopment analysis (DEA) to evaluate the ability of scientific and technological achievements of 39 universities in Jiangsu Province.[2] Xiuhua Yang and Peiguo Yu (2014) conducted a study on the efficiency of transformation of scientific and technological achievements in Chinese universities based on the DEA method.[3] Weimin Wei and Feiyue Zhou (2006) used a comprehensive fuzzy evaluation method to establish a comprehensive fuzzy evaluation model for the research performance of university scientific and technological achievements.[4] Yan Zhu (2016) combined with the development stage of transformation of scientific and technological achievements in universities, established an index system for the evaluation of transformation of scientific and technological achievements in universities, in terms of basic research, experimental research, achievement transformation, industrial promotion, and transformation of environmental indicators in the transformation of university scientific and technological achievements. Using the improved analytic hierarchy process to determine the weight of each index, the industrial extension research of university scientific and technological achievements was carried out.[5]

In addition, scholars use examples or empirical analysis methods to research scientific and technological achievements in universities. Guiyue Wang and Shuen Wang (2009) selected 16 evaluation indicators using the good predictive ability of neural networks, and established an evaluation model for the transformation of scientific and technological achievements in universities based on fuzzy neural network, and conducted an example analysis.[6] Junhua Guo and Nini Xu (2016) used factor analysis methods and clustering methods to establish an evaluation index system for university science and technology achievement conversion capacity to analyze empirically the transformation capability of university scientific and technological achievements from the three dimensions of transformation conditions, transformation strength and transformation effects. The study found that there is a big difference in the ability of transforming scientific and technological achievements between universities.[7]

At present, the research on the transformation of scientific and technological achievements in colleges and universities focuses on the construction of the overall index system, and rarely evaluates and empirically measures the transformation of scientific and technological achievements in regional universities. Based on previous research

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results, this paper uses Delphi and Analytic Hierarchy Process (AHP) to construct a Beijing, Tianjin, and Hebei colleges and universities scientific and technological achievements conversion ability evaluation system and collect data for an empirical analysis from the perspectives of transformation potential of science and technology achievements, research activities, and transformation of achievements.

3. Measurement Index System Design

Input-output analysis is a kind of economic quantitative analysis method that was researched by the famous American economist Vasily Lyonkov in the 1930s.[8]The theoretical basis of the input-output model is Vasily's general equilibrium theory. Input-output analysis is an economic quantitative method that studies the interdependence of inputs and outputs among various parts of the economic system. Input is the consumption of an activity. Output refers to the result of an activity. This article relies on the general equilibrium theory and input-output model to determine the factors of the vertical achievements of the universities, the results of horizontal cooperation, and the transformation efficiency of achievements in the Beijing-Tianjin-Hebei colleges and universities, and establish the first-level indicators from the transformation potentials, scientific research activities, and achievement transformation of university scientific and technological achievements. Two secondary indicators and 17 tertiary indicators were used to construct a Beijing-Tianjin-Hebei university science and technology achievement transformation performance evaluation system.

3.1 Selection of evaluation indicators

In the performance evaluation of university scientific and technological achievements conversion, the conversion potential, scientific research activities and the transformation of scientific and technological achievements are considered in three aspects. The potential for transformation is the precondition and basis for the development of science and technology. The process of scientific and technological activities is the practical stage of scientific and technological work. The transformation of scientific and technological achievements is the outcome of technological activities. Conversion potential, scientific research activities, and scientific and technological achievements represent different stages of the science and technology process. The assessment indicators of each stage should be different. Comprehensive evaluation of the three aspects can reasonably reflect the level and strength of the entire process of scientific and technological development of universities and colleges in Beijing, Tianjin, and Hebei.

3.1.1 Conversion Potential

The transformation potential reflects the level of colleges and universities, the transformation potential of colleges and universities affects the efficiency of transformation of scientific and technological achievements in universities, including human and financial inputs.

Scientists and technicians are the main bodies that promote the development of science and technology. The number of R&D personnel in higher education institutions and personnel of scientific research institutions in higher education institutions reflects, to a certain extent, the size of personnel engaged in science and technology research and development in colleges and universities. Therefore, the number of R&D outcomes applications and scientific and technical service personnel in higher education institutions and the number of scientific research institutions in higher education institutions are selected as important indicators for assessing the human input status of the transition of scientific and technological achievements in universities and colleges in Beijing, Tianjin and Hebei.

In the scientific research process of colleges and universities, funds are the basis for scientific and technological activities. Funds investment includes basic research funding, application research funding, and experimental development funding for colleges and universities, reflecting the funding input for the scientific research process. Therefore, the selection of funding is an important indicator to measure the scale of college investment and scientific and technological strength.

3.1.2 Scientific and Technological Activities

Scientific and technological activities are the practical stages of scientific and technological work and are closely related to the creation, development, dissemination and application of scientific and technological knowledge. The depth and breadth of scientific and technological activities reveal to some extent the strength of scientific and technological strength. Scientific research institutes, colleges and universities and large and medium-sized enterprises are the subjects engaged in scientific research and technological development. They are the grass-roots units that carry out scientific and technological research and are the main bearers of scientific and technological activities. Scientific research and technological development and promotion are the main contents of scientific and technological activities. The number of scientific and technological activity units and the number of various types of research projects (projects) are important indicators that reflect the strength of regional science and technology. There is no country with a big economy, a country with strong science and technology, nor can a country with strong education comprehensively analyze and evaluate the scientific and

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technological strength of a country or region. It should not only see the current state of the development of science and technology, but also pay attention to its future development potential. College students are the backup forces of future scientists and engineers. Therefore, the number of graduate students and the number of students participating in the research project are also an important measure of scientific and technological strength.

3.1.3 Achievement Transformation

The level of achievement transformation in colleges and universities reflects the degree of scientific and technological innovation ability and the activity of science and technology in colleges and universities. This article selected four secondary indicators of monographs, scientific papers, patents and technology trade. The quantity and quality of monographs and scientific papers are one of the important indicators for the evaluation of outcomes. The number of patents is the number of patented inventions created, and the number of patent grants reflects the university's technological innovation capabilities. Technology trade reflects the innovation and digestion and absorption capabilities of colleges and universities, and it is an effective way for science and technology to be transformed into productive forces. This article selects the technical market turnover and the number of technical market transactions, two three-level indicators to assess the level of science and technology trade in colleges and universities.

3.2 Determination of Weights

In order to determine the weight of indicators, first select experts to score each indicator. Using the analytic hierarchy process, we compare the importance of each factor at the same level with respect to the previous criterion level, calculate the weights of the elements of each layer on the system target, and use the group decision method to obtain each level of weight.[9] The index system design is shown in Table 1.

Table 1. Evaluation Index System for the Transformation of Scientific and Technological Achievements in Universities

First-level indicators	Second-level indicators	Third-level indicators
Conversion potential (0.27)	Human input（0.56）	P_1 R & D Results Application and Technology Service Staff（0.33）
		P_2 Number of Staff of Scientific Research Institutions in Colleges and Universities（0.67）
	Funding（0.44）	K_1 Funding for basic research in colleges and universities（0.26）
		K_2 Higher education applied research funding（0.41）
		K_3 Higher education funding for experimental development（0.32）
Science and technology activities (0.24)	talent Development（0.40）	TD_1 Number of non-professional personnel engaged in research and development(0.37)
		TD_2 The number of graduate students in the research project(0.24)
		TD_3 The number of research projects in the current year(0.40)
	Research institutions（0.24）	*M* Number of research institutions in institutions of higher learning(1.00)
	research subject（0.36）	RS_1 Higher Education Research Project(0.18)
		RS_2 The number of participants in the year（people）(0.31)
		RS_3 Funding for the year（1000yuan）(0.30)
		RS_4 Expenditure for the year（1000yuan）(0.21)
Achievements (0.49)	Professional writing（0.19）	*B* Research institutes(1.00)
	Scientific Papers（0.20）	*TH* Universities publish scientific papers(1.00)
	patent（0.21）	*RA* Number of Patent Grants in Colleges and Universities(1.00)
	Technical trade（0.40）	TC_1 Technical market turnover(0.56)
		TC_2 Technical market turnover contract number(0.44)

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4. Empirical Measurements of Scientific and Technological Achievements Transformation in Colleges and Universities in Beijing, Tianjin, and Hebei

In order to understand the level and ranking of scientific and technological transformation of universities and colleges in Jing-Jin-Ji, the data from the Statistics of Science and Technology Statistics in Colleges and Universities from 2012 to 2016 were used for empirical analysis.According to the evaluation index system for science and technology transformation , the values of 206 indicators are shown in Table 2.

Table 2. Evaluation Index Data of the Transformation of Scientific and Technological Achievements of Colleges and Universities in Beijing, Tianjin, and Hebei in 2016

project	Beijing	Tianjin	Hebei
P_1/people	3735	299	1138
P_1/people	39312	10995	10218
K_1/10000yuan	637.1411	69.8095	30.3028
K_2/10000yuan	901.4908	219.1862	63.1680
K_3/10000yuan	76.5421	28.4092	2.8468
TD_1/people	329	70	19
TD_2/people	49357	12476	3425
TD_3/people	11712	4312	1974
M/piece	644	194	136
RS_1/piece	61907	13007	10063
RS_2/people	28700	7532	7572
RS_3/1000yuan	18612634	3445630	1460823
RS_4/1000yuan	14560361	3157551	1244369
B/item	509	43	133
TH/piece	85613	23122	23586
PA/item	9207	2079	2632
TC_1/1000yuan	960813	127662	59669
TC_2/item	938	182	338

Notes: There are more data from 2012 to 2016; only 2016 data are listed here.

To evaluate the ability of Beijing-Tianjin-Hebei university science and technology achievements transformation, the same group of source data should be weighted and ranked in the same evaluation index system and the same evaluation model. In order to make the evaluation result more consistent with the objective reality, eliminating the influence of different disparities in the overall data and the incomparable factors between the indicators, and playing the role of the same measure, a comprehensive index weighting method was adopted. In the evaluation index system, the unit of measurement of each index is different, and it is not fair, and cross-computing and comparative analysis cannot be performed. It is necessary to perform dimensionless processing first. Here, we use the indexed processing method. Exponential processing takes the difference between the maximum value and the minimum value of the index to calculate the index of the index, and uses the product of the relative weight of each index and its composite index as the evaluation value of the index to accumulate the evaluation value of each index. The sum is the conversion value of scientific and technological achievements. The formula is:

$$M_{(t)} = \sum_{i=1}^{m} R_i e_i$$

In the formula, $M_{(t)}$ is the t-level scientific and technological achievements transformation strength evaluation value ; R_i is the weight of index i relative to the target ; e_i is a measure of the value of the indicator i through the dimensionless indicator. This formula can also be used to comprehensively evaluate different indicators of each level of the evaluation index system to facilitate analysis and comparison. Using the above evaluation index system and evaluation method, the scientific and technological transformation capacity of universities in Beijing, Tianjin, and Hebei was evaluated and calculated from 2012 to 2016. The results of the first level evaluation are shown in Table 3.

Table 3. Evaluation of Scientific and Technological Achievements Transformation of Colleges and Universities in Beijing, Tianjin, and Hebei from 2012 to 2016

Time	project	Conversion potential	Science and technology activities	Achievements
2012 year	Beijing	0.2376	0.4234	0.5998
	Tianjin	0.0098	0.0358	0.0105
	Hebei	0.0169	0.0000	0.0202
2013 year	Beijing	0.2376	0.4234	0.5998
	Tianjin	0.0253	0.0395	0.0165
	Hebei	0.0178	0.0000	0.0335
2014 year	Beijing	0.2376	0.4234	0.5998
	Tianjin	0.0420	0.0468	0.0115
	Hebei	0.0168	0.0000	0.0396
2015 year	Beijing	0.2376	0.4234	0.5998
	Tianjin	0.0290	0.0657	0.0067
	Hebei	0.0118	0.0000	0.0920
2016 year	Beijing	0.2376	0.4234	0.5998
	Tianjin	0.0327	0.0535	0.0083
	Hebei	0.0122	0.0001	0.0671

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5. Conclusion

From the above analysis results, it can be seen that there is a gap in the ability of Beijing-Tianjin-Hebei University to transform scientific and technological achievements, and the level of scientific and technological achievements in the Inter-regional Science Division is extremely unbalanced. Under the overall trend, colleges and universities in Beijing are in absolute superiority in the process of transforming scientific and technological achievements of universities and colleges in Beijing, Tianjin and Hebei, and their overall strength ranks first. There is a certain gap between the strength of science and technology transformation in Tianjin and Hebei universities and Beijing, and this situation has not been significantly improved in recent years.

The value of transformation of scientific and technological achievements in universities in Beijing has remained at a value of 0.59 or more. This shows that it has a relatively high level of transforming achievements. From its transformation potential and scientific and technological activities, it can also be seen that its transformation potential and science and technology activity index are also among the top three universities. Obviously, Beijing belongs to the "three strong" regions with superior conversion conditions, active scientific and technological activities, and strong transformation. From the data analysis results, it can be seen that the conversion potential value of Tianjin in 2012 was 0.0098, which was lower than that of Beijing and Hebei. The technology conversion value from 2013 to 2016 was lower than that of Beijing but higher than Hebei, and its value was basically double that of Hebei Province. It shows that Tianjin universities have invested a certain amount in scientific and technological human and financial support.

The lack of investment in science and technology and the inactivity of scientific and technological activities are the key factors that restrict the transformation of scientific and technological achievements in universities and colleges in Hebei. From the analysis of the data, it can be seen that the transformation efficiency of scientific and technological achievements in colleges and universities in Hebei Province is lower than that in Beijing and Hebei. This is reflected not only in the lack of scientific and technological manpower input and financial support, but also in the lack of vitality in science and technology activities. During the period of assessment, it was shown that in terms of personnel training, research institution construction, and research projects, Hebei universities are lagging behind in the three universities, and in recent years there has been no significant change.

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