Modeling and Empirical Analysis of Regional Science and Technology Innovation Performance Evaluation Index System

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Abstract. Comprehensive and accurate evaluation of regional science and technology innovation performance is the basis for building a new area of technological innovation. In this paper, using principal component analysis method, aiming at the scientific and technological innovation performance data of Jiangsu Province in the past five years, combined with the characteristics of science and technology innovation of local education, enterprise, industry, economy and high-tech industry, the three-layer performance index evaluation system is constructed through SPSS software. The system consists of 15 three-level indicators under three secondary indicators. Under the different weight distribution conditions, the final first-level evaluation score index is obtained. Based on the analysis of data from Jiangsu Province from 2012 to 2016, this paper concludes that the performance level of science and technology innovation in Jiangsu Province is increasing year by year.

1. Introduction

Human society has entered an important period in which technological innovation is constantly emerging [1]. The global scientific and technological revolution is booming, and high-tech innovation has become the core driving force for the development of a country or region. Only a comprehensive and objective understanding of the status quo of scientific and technological innovation, accurate and appropriate selection of relevant indicators, scientific and rational use of measurement methods, can accurately measure and evaluate its performance, and further provide a reliable and solid improvement of existing policies and methods. The theoretical basis and basis for the purpose of continuously enhancing the strength of China's scientific and technological innovation, so that China's social and economic aspects have gained strong competitive strength, comprehensive national strength has been rapidly improved, and the road to scientific and technological innovation can present a sustainable virtuous cycle of development.

In recent years, China's overall economic level has developed rapidly, regional economic levels have improved significantly, scientific and technological innovation activities have become increasingly active, and the role of technological innovation has become increasingly prominent in regional development. The city is the carrier of national and regional competitiveness [2]. Under the background of increasing economic competition, it is necessary to increase the research on urban science and technology innovation. The evaluation of urban science and technology innovation ability will promote the development of urban science and technology, economy and society. It has great practical significance.

As the actual evaluation system becomes larger, digital, intelligent and integrated, the comprehensive evaluation method has become a hot topic in academic research. Comprehensive evaluation methods such as fuzzy comprehensive evaluation [3], expert evaluation method [4] and analytic hierarchy process are also widely used in some fields. However, there is still no systematic research on the evaluation system and model of regional science and technology innovation performance. Therefore, it is urgent to carry out research work on regional science and technology innovation performance evaluation, in order to find a suitable evaluation method and corresponding mathematical model, which can reasonably evaluate the regional science and technology innovation performance.

2. Establishment of Performance Evaluation Index System Model

2.1 Research Background

The process of constructing the regional science and technology innovation performance evaluation index system model is a process of gradually deepening the understanding of the quality characteristics of the evaluation object, gradually refining and perfecting. The scientific and reasonable, simple and practical index system is the basis for doing a good job in evaluation [5]. In the process of designing the evaluation index system, we should use the method of system analysis, combined with the development of China's development, and draw on the results of relevant research at home and abroad, such as the four combination evaluation methods proposed by Xianguang Guo [6], based on Zhigang Gao [7], the combination evaluation method of two methods, such as principal component analysis and analytic hierarchy process, the evaluation index system established by SC Gao [8], and the urban technology innovation capability evaluation system constructed by A Hashimoto and S Haneda [9], strive to fully summarize and fully reflect on the basis of the essential connotation and characteristics of regional science and technology innovation, we design an index system model that can comprehensively reflect regional technological innovation and facilitate operation.

The construction of the regional science and technology innovation performance evaluation index system model is divided into three levels [10], which are the target layer, the decision layer and the indicator layer.

2.2 Regional Science and Technology Innovation Performance Evaluation Target Layer

The target layer is the comprehensive score index of regional science and technology innovation performance evaluation. The index gives the final scientific and technological innovation performance score of the research area on the basis of comprehensive indicators.

2.3 Regional Science and Technology Innovation Performance Evaluation Decision Layer

Scientific and technological innovation is an important way for regions or enterprises to obtain core competitiveness [11]. The growth of regional core competitiveness depends on regional science and technology innovation. Considering the development of regional science and technology innovation, it depends on the basic talent training in the region [12], government support, corporate strategy, industrial development structure, output value feedback and other factors. We give the following three types of indicators for the decision layer.

(1) Performance indicators of research and education institutions;

(2) Performance indicators of government enterprises and institutions;

(3) Performance indicators of Technological innovation output;

Among them, the first category mainly considers human resources, that is, the input of technical human resources and the investment of basic scientific research facilities; the second category mainly considers the government's support for scientific and technological innovation, as well as enterprises and institutions due to the pressure of technological innovation and competition, The emphasis on innovation investment and the adjustment of development structure and strategy; the third category focuses on performance, which is the actual performance brought by technological innovation, that is, output value and income [13].

2.4 Regional Science and Technology Innovation Performance Evaluation Index Layer

On the basis of decision level, taking into account the performance of scientific and technological innovation research and education institutions, it is mainly reflected in human resources, technical human resources training, infrastructure investment and modern facilities construction; technology innovation government enterprise performance, mainly reflected in finance at all levels Funds directly allocated to scientific and technological activities [14], enterprises and institutions invested in research and experimental development (R&D) [15], and the importance of enterprises for scientific and technological innovation and technological improvement; performance is mainly reflected in scientific and technological achievements [16], namely basic theoretical results, applied technical achievements and soft scientific achievements, as well as the amount of patent applications granted, as well as the economic benefits brought by high-tech output. In this regard, the structure of the regional science and technology innovation performance evaluation index system is constructed, as shown in Figure 1.

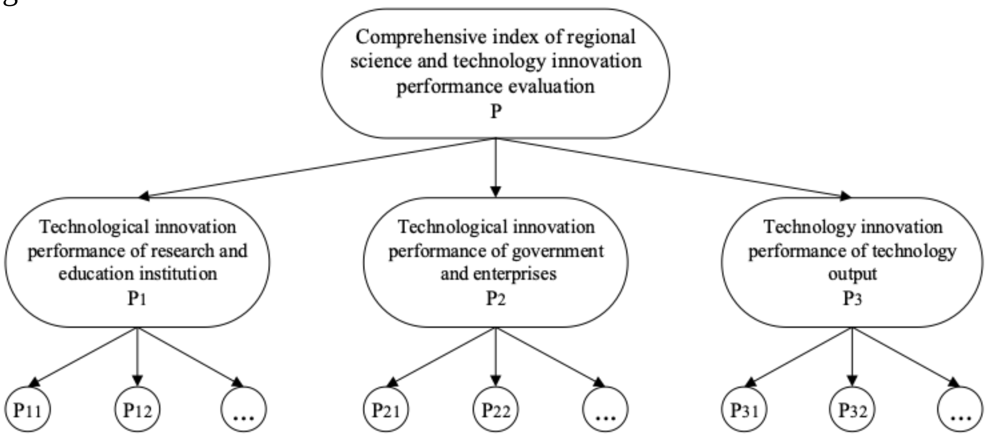

Figure 1. Indicator architecture diagram.

According to the index architecture, the regional science and technology innovation performance evaluation index system model has three levels, namely the target layer, the decision layer and the indicator layer. Among them, the target layer is the regional science and technology innovation evaluation index system; the decision layer selects the indicators from the three dimensions of performance, scientific and technological innovation [17], government and enterprise performance, and high-tech output performance of science and technology innovation. There are 15 specific indicators in the indicator layer. The details are shown in Table 1.

Table 1. Indicator system model.

Target layer	Decision layer	Indicator layer
Regional Science and Technology Innovation Performance Evaluation System P	Research and education institution performance P1	P11 Research and development topics (EA)
		P12 Number of scientific and technological personnel (10,000 people)
		P13 Research and development expenditures as a percentage of regional GDP (%)
		P14 Number of scientific research institutions (EA)
	Government and enterprises performance P2	P21 Government grant (100 million ¥)
		P22 Total R&D expenditure (100 million ¥)
		P23 Number of R&D companies (EA)
		P24 Number of research and development projects in industrial enterprises (EA)
		P25 Total expenditure on technological transformation (100 million ¥)
	Technological innovation output performance P3	P31 Number of scientific and technological achievements (EA)
		P32 Number of invention patents (EA)
		P33 High-tech industry output value (100 million ¥)
		P34 Research and development expenditure (10,000 ¥)
		P35 Per capita GDP (¥)
		P36 The output value of high-tech industries accounts for the proportion of total industrial output (%)

3. Empirical Analysis of Performance Evaluation Index System Model

3.1 Selection of Research Samples

This paper selects the basic indicators of Jiangsu Province from 2012 to 2016 as the research samples. The initial data of each indicator are shown in Table 2.

Table 2. Initial data.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
2012	97602	98.23	2.33	17776	49.52	1117.14	11133	44575	717.89	7877	27820	45041.48	1211365	68347	37.5
2013	107690	109.46	2.45	19393	52.68	1278.97	12283	48559	642.14	8021	33090	51899.1	1339448	75354	38.5
2014	118467	115	2.54	21844	57.76	1445.28	14150	53117	603.13	8443	39858	57277.28	1417795	81874	39.5
2015	122629	111.99	2.57	23101	54.94	1562.07	18872	51720	507.2	7970	37407	61373.61	1449858	87995	40.1
2016	138251	117	2.66	25402	72.06	1712.94	19186	59535	521.95	9966	49229	67124.65	1600660	95257	41.5

3.2 Data Preprocessing

In order to eliminate the problems caused by the unit, meaning and order of magnitude inconsistency between multiple sets of data, we need to standardize the initial data and compare it with the standardized data. The normalization process eliminates the effects of varying magnitudes and dimensions between variables, resulting in groups of variables with an average of 0 and a variance of 1.

The standardization formula is as follows:

$$P_{ij}^{*} = \frac{P_{ij} - \bar{P}_j}{\sigma_j} \quad (i = 1,\ 2 \dots p) \tag{1}$$

among them, $\bar{P}_j = \frac{1}{n}\sum_{i=1}^{n} P_{ij}$, $\sigma_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(P_{ij} - P_j)^2}$

With SPSS software, standardized data can be obtained directly using descriptive statistical processes. Specific steps are as follows:

Select the menu "Analysis", select the menu "Description Statistics", select the menu "Description", in the "Descriptive" dialog box, select P11~P36 into the "Variables" box, and select "Save the standardized score as a variable" Check box, and finally click the "OK" button to get standardized data as shown in Table 3.

Table 3. Standardized data.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
2012	-1.255	-1.647	-1.434	-1.239	-0.901	-1.311	-1.072	-1.245	1.370	-0.663	-1.207	-1.352	-1.342	-1.276	-1.257
2013	-0.600	-0.119	-0.478	-0.701	-0.539	-0.618	-0.763	-0.529	0.501	-0.498	-0.549	-0.546	-0.449	-0.610	-0.602
2014	0.100	0.634	0.239	0.113	0.042	0.094	-0.262	0.290	0.053	-0.014	0.297	0.086	0.097	0.010	0.052
2015	0.370	0.225	0.478	0.531	-0.281	0.594	1.006	0.039	-1.047	-0.557	-0.009	0.568	0.321	0.593	0.445
2016	1.385	0.906	1.195	1.296	1.678	1.240	1.090	1.444	-0.878	1.733	1.468	1.243	1.373	1.283	1.362

3.3 Principles and Empirical Steps of Principal Component Analysis

Principal component analysis is a multivariate statistical method that examines the correlation between multiple variables [18]. It is a study of how to interpret the internal structure between multiple variables with a few principal components. That is to say, a few principal components are derived from the original variables, so that they retain as much information as possible of the original variables, and are not related to each other. The application purpose of principal component analysis can be simply summarized as: data compression and data interpretation. It is often used to find comprehensive indicators of certain things or phenomena, and to give appropriate explanations to the information contained in the comprehensive indicators, thus revealing the inherent laws of things more deeply.

For m evaluation indicators: P_1, P_2, $P_3 \cdots P_m$, when comparing between n units, there are m*n data, which constitute an evaluation index matrix *P*:

$$P = \begin{pmatrix} P_{11} & P_{12} & \cdots & P_{1m} \\ P_{21} & P_{22} & \cdots & P_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nm} \end{pmatrix} \quad (2)$$

Principal component analysis uses m primitive variables (P_1, P_2, $P_3 \cdots P_m$) to construct a few new synthetic variables, so that the new variables are linear combinations of the original variables, the new variables are not related to each other, and the new variables contain m original variables. Most of the information. Define the comprehensive variable indicators: W_1, W_2, $W_3 \cdots W_t$, component score coefficients: l_1, l_2, $l_3 \cdots l_m$, and the integrated variable indicator is a linear combination of the original variables.

$$\begin{cases} W_1 = l_{11}P_1 + l_{12}P_2 + \cdots + l_{1m}P_m \\ W_2 = l_{21}P_1 + l_{22}P_2 + \cdots + l_{2m}P_m \\ \vdots \\ W_t = l_{t1}P_1 + l_{t2}P_2 + \cdots + l_{tm}P_m \end{cases} \quad (3)$$

Among them, each variable is required to meet the following conditions:

(1) W_i and W_j (i, j = 1, 2, ..., t) are not related to each other;

(2) W_1 is the largest variance of the linear combination of P_1, P_2, $P_3 \cdots P_m$;

(3) W_1, W_2, $W_3 \cdots W_t$ are the first, second, ..., tth principal components of P_1, P_2, $P_3 \cdots P_m$;

The essence of principal component analysis is to determine the coefficients l_1, l_2, $l_3 \cdots l_m$ of the original variables P_1, P_2, $P_3 \cdots P_m$ on each of the principal components W_1, W_2, $W_3 \cdots W_t$. From the mathematical analysis, they are the eigenvectors corresponding to the larger t eigenvalues of the m original variables P_1, P_2, $P_3 \cdots P_m$ correlation matrices, respectively, and the variance var of the W_i of each comprehensive variable $var(W_i)$ is exactly the corresponding feature root λ_i. The variance contribution rate of each principal component is arranged in the order of the feature roots, which is sequentially decreasing, that is, $\lambda_1 > \lambda_2 > \cdots > \lambda_m > 0$.

Finally, for each comprehensive variable index, the composite contribution rate is calculated by using the variance contribution rate as the weight.

According to the principal component analysis method, based on the regional science and technology innovation index data from Jiangsu Province from 2012 to 2016, the SPSS software is used to calculate the correlation coefficient matrix R. The equation is as follows:

$$\mathrm{R} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mm} \end{pmatrix} \quad (4)$$

r_{ij}(i, j = 1, 2, … , m) is the correlation coefficient between the original variables P_i and P_j, $r_{ij} = r_{ji}$, and the formula is as follows:

$$r_{ij} = \frac{\sum_{k=1}^{n}(P_{ki} - \overline{P_i})(P_{kj} - \overline{P_j})}{\sqrt{\sum_{k=1}^{n}(P_{ki} - \overline{P_i})\sum_{k=1}^{n}(P_{kj} - \overline{P_j})}} \quad (5)$$

Table 4. Correlation coefficient matrix.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
P11	1.000	.885	.986	.994	.920	.991	.915	.981	-.905	.831	.976	.991	.996	.991	.999
P12	.885	1.000	.940	.872	.758	.887	.726	.904	-.828	.647	.892	.900	.910	.869	.877
P13	.986	.940	1.000	.985	.858	.991	.906	.963	-.936	.748	.954	.994	.989	.986	.986
P14	.994	.872	.985	1.000	.881	.998	.945	.959	-.934	.780	.953	.995	.984	.997	.997
P21	.920	.758	.858	.881	1.000	.858	.728	.958	-.671	.982	.965	.861	.917	.867	.905
P22	.991	.887	.991	.998	.858	1.000	.950	.950	-.953	.748	.941	.999	.985	.999	.995
P23	.915	.726	.906	.945	.728	.950	1.000	.819	-.969	.606	.806	.942	.894	.957	.932
P24	.981	.904	.963	.959	.958	.950	.819	1.000	-.816	.891	.999	.953	.983	.948	.971
P25	-.905	-.828	-.936	-.934	-.671	-.953	-.969	-.816	1.000	-.524	-.798	-.952	-.900	-.951	-.921
P31	.831	.647	.748	.780	.982	.748	.606	.891	-.524	1.000	.904	.751	.828	.761	.811
P32	.976	.892	.954	.953	.965	.941	.806	.999	-.798	.904	1.000	.944	.977	.939	.965
P33	.991	.900	.994	.995	.861	.999	.942	.953	-.952	.751	.944	1.000	.989	.998	.995
P34	.996	.910	.989	.984	.917	.985	.894	.983	-.900	.828	.977	.989	1.000	.985	.994
P35	.991	.869	.986	.997	.867	.999	.957	.948	-.951	.761	.939	.998	.985	1.000	.996
P36	.999	.877	.986	.997	.905	.995	.932	.971	-.921	.811	.965	.995	.994	.996	1.000

Table 4 shows the matrix of correlation coefficients between the original variables. It is easy to see that there is a strong correlation between many variables, and there is overlap of information to some extent.

Table 5. Common factor variance.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
Initial value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extract	.999	.807	.981	.988	.832	.984	.833	.961	.830	.672	.950	.987	.995	.984	.997

Table 5 shows the common factor variance. Wherein, the “Initial value” is the variance of the common value of the original value, indicating that the factor extracts the sum of the squares of the load coefficients of all the common factors of each variable, and the value is 1; the “Extract” is to extract the common factor variance, indicating that the extraction is based on a certain principle. The common factor, the number of common factors is less than or equal to the number of variables.

Corresponding to the correlation coefficient matrix R, the principal component contribution rate and the cumulative contribution rate can be calculated, and the calculation formula is as follows:

Contribution rate:

$$\frac{\lambda_i}{\sum_{k=1}^{m}\lambda_k}(i=1,2,\dots,m) \tag{6}$$

Cumulative contribution rate:

$$\frac{\sum_{k=1}^{i}\lambda_k}{\sum_{k=1}^{m}\lambda_k}(i=1,2,\dots,m) \tag{7}$$

where $\lambda_i(\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m \geq 0)$ is the eigenvalue.

Table 6. Explanation of total variance.

Component	Initial Eigenvalue			Extract the Sum of Squared Loads		
	Total	Percentage of Variance	Cumulative %	Total	Percentage of Variance	Cumulative %
1	13.799	91.996	91.996	13.799	91.996	91.996
2	.870	5.802	97.798			
3	.316	2.105	99.903			
4	.015	.097	100.000			
5	1.371E-15	9.143E-15	100.000			
6	3.862E-16	2.575E-15	100.000			
7	2.454E-16	1.636E-15	100.000			
8	1.314E-16	8.757E-16	100.000			
9	3.683E-17	2.455E-16	100.000			
10	-8.485E-17	-5.657E-16	100.000			
11	-1.677E-16	-1.118E-15	100.000			
12	-2.517E-16	-1.678E-15	100.000			
13	-3.959E-16	-2.639E-15	100.000			
14	-4.826E-16	-3.217E-15	100.000			
15	-8.560E-16	-5.706E-15	100.000			

The “Initial Eigenvalue” column in Table 6 shows the variance of the principal component scores arranged in order, the value of which is equal to the eigenvalues of the correlation coefficient matrix, and the “Percentage of Variance” of the principal component can be calculated according to the eigenvalue, and then the percentage of variance of the principal component, and the “Cumulative” of the variance is calculated. In the column “Extract the Sum of Squared Loads”, a principal component and related parameters whose feature roots greater than 1 extracted from the “Initial Eigenvalue” column are displayed. It can be seen from the table that the ratio of the first factor contribution to the total variance is about 90% [19], which can summarize most of the information of the original data. Therefore, it is better to use the principal component analysis method for evaluation.

Table 7. Composition matrix.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
Component	.999	.898	.990	.994	.912	.992	.913	.980	-.911	.819	.974	.993	.997	.992	.999

Table 7 is the main component load matrix, in which the “Component” is the load factor of the main component, and the different load values represent the correlation coefficient between the different variables and the principal component. For example, 0.999 indicates the correlation coefficient between the number of R&D topics and the principal component, that is, the load on the principal component of the number of R&D topics.

It can be seen from Table 7 that, except for the number of scientific and technological personnel and the number of scientific and technological achievements, there is a high correlation coefficient with the principal component, in which the correlation coefficient between the total amount of technological transformation expenditure and the principal component is negative, that is, it shows a negative correlation. Relationship, combined with actual analysis, the higher the level of scientific and technological innovation, the less funds that need to be invested in technological transformation, which is in line with the actual situation.

Table 8. Component Score Coefficient Matrix.

	P11	P12	P13	P14	P21	P22	P23	P24	P25	P31	P32	P33	P34	P35	P36
Component	.072	.065	.072	.072	.066	.072	.066	.071	-.066	.059	.071	.072	.072	.072	.072

According to the matrix of component score coefficients in Table 8, the score expression of the principal component can be obtained as:

$$\begin{aligned} W = {} & 0.072\text{P}11 + 0.065\text{P}12 + 0.072\text{P}13 + 0.072\text{P}14 + 0.066\text{P}21 + 0.072\text{P}22 \\ & + 0.066\text{P}23 + 0.071\text{P}24 - 0.066\text{P}25 + 0.059\text{P}31 + 0.071\text{P}32 \\ & + 0.072\text{P}33 + 0.072\text{P}34 + 0.072\text{P}35 + 0.072\text{P}36 \end{aligned} \tag{8}$$

By bringing the standardized data into the above-mentioned principal component score expression, the annual scientific and technological innovation performance scores of Jiangsu Province from 2012 to 2016 can be calculated, as shown in Table 9.

Table 9. Performance score.

	2012	2013	2014	2015	2016
Score	-1.29	-0.56	0.12	0.38	1.36

4. Results Analysis

According to Table 9, the average regional science and technology innovation performance score of Jiangsu Province from 2012 to 2016 is 0.005, and the regional science and technology innovation performance scores from 2014 to 2016 are above the average. The regional technology innovation performance in 2013 was 56.59% year-on-year. The regional science and technology innovation performance in 2014 was 121.43% year-on-year. The regional technology innovation performance in 2015 was 216.67%, and the regional technology innovation performance in 2016 was year-on-year. The growth rate is 257.89%, with a significant increase year by year.

A comprehensive analysis of the above findings can lead to the following conclusions:

(1) Comparing the actual situation of scientific and technological innovation development in Jiangsu Province in the past 5 years [20], the evaluation results basically reflect the development status of regional science and technology innovation performance in Jiangsu Province, indicating that the evaluation index system established in this paper can be more objective to regional technology evaluation of innovation performance.

(2) As a province of science and technology in China, Jiangsu Province ranks first in the country in terms of the amount of science and technology basic resources and high-tech industries, and has a sound scientific and technological innovation industry foundation, and has a comprehensive scientific and technological innovation development system. In recent years, Jiangsu's science and technology innovation industry has achieved great results, not only in the rapid development of high-tech industries, but also in the emerging industries.

(3) At present, like many other regions in China, Jiangsu Province is in a critical period of creating innovative provinces. How to understand regional innovation capabilities accurately while improving scientific and technological innovation capabilities has become the focus of work in various regions. Therefore, through the regional scientific and technological innovation performance evaluation index system constructed in this paper, the evaluation of regional science and technology innovation capability in Jiangsu Province and other regions has strong theoretical and practical value.

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