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DYNAMIC EVALUATION OF SCIENCE AND TECHNOLOGY INNOVATION BASED ON CLUSTER AHP-ENTROPY WEIGHTING METHOD

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Abstract. Existing methods of assigning weights to the science and technology innovation (STI) index system mainly focus on the single use of subjective or objective methods, which cannot adequately reflect the combination of expert experience and actual objective data. This study aimed to evaluate the level of STI capability of 12 leagues and cities in Inner Mongolia. First, the subjective weight judgment matrix of multi-expert recognition was measured using cluster analytical hierarchy process (AHP), the objective weights were measured by the entropy weighting method, and then the dynamic weights and dynamic scores of the STI capability of each alliance and city in Inner Mongolia were comprehensively evaluated. The empirical results showed that (1) the turnover of technology contracts, the proportion of local financial science and technology allocations to local financial expenditures, the per capita year-end loans of financial institutions, and the per capita gross domestic product were the main factors affecting the regional STI capability of Inner Mongolia; (2) the STI score of Hohhot was the highest, and the STI score of Xing' anmeng was the lowest. The results of the comparative analysis showed that the evaluation results of the STI capability of Inner Mongolia's leagues and cities obtained using the methodology proposed in this study were stable.

1. Introduction

In 2021, the General Office of the People's Government of the Inner Mongolia Autonomous Region issued the regional "14th Five-Year Plan" notice of science and technology innovation (hereinafter referred to as STI), further propelling the growth of STI in Inner Mongolia. The policy report states that the "14th Five-Year" period is a crucial phase for innovation-driven, high-quality development. Inner Mongolia, more than ever, requires STI to play a more critical and robust supporting and leading role. However, limited STI capability remains a constraint on Inner Mongolia's high-quality development and the establishment of a new development framework. Therefore, evaluating the level of STI in Inner Mongolia is the prerequisite and key to innovation-driven, high-quality development as well as the promotion of science and technology development in Inner Mongolia. Hence, this study explored the STI ability of 12 leagues and cities in Inner Mongolia. First, the weights of STI evaluation indexes were measured using the cluster analytical hierarchy process

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(AHP)–entropy weighting method. We further obtained the dynamic scores of the STI of each city for a comprehensive and dynamic evaluation of the STI capability of each city in Inner Mongolia to provide guidance and theoretical references for developing the regional STI in Inner Mongolia in the future. The empirical results showed that (1) the turnover of technology contracts, the proportion of local financial science and technology allocations to local financial expenditures, the per capita year-end loans of financial institutions, and the per capita gross domestic product were the main factors affecting the regional STI capability of Inner Mongolia; and (2) the STI score of Hohhot was the highest, and the STI score of Xing'anmeng was the lowest.

The current status of STI evaluation methods:

(1) Evaluation of subjective empowerment methods

Qi [4] evaluated the talent of the STI think tank based on the AHP method and the 5-point Likert scale. The results showed that the evaluation indexes for STI think tank talent under the model were more scientific and reasonable. Yang [8] evaluated the sustainable development level of rural tourism in Huangqiao Town based on AHP-fuzzy mathematics. The evaluation results indicated that the comprehensive score for the sustainable development level of the rural tourism resources in the place was rated as "good". Chen [1] used the AHP method to calculate the weights to assess the customer knowledge management ability of the farmhouse enterprises.

(2) Evaluation of objective empowerment methods

Zhang [10] evaluated STI platforms based on technology readiness and the gray clustering evaluation model. Ozkaya [3] used the entropy method to determine the weights of the evaluation indexes of STI, and used TOPSIS, VIKOR, PROMETHEE I-II, ARAS, COPRAS, MULTIMOORA, ELECTRE, SAW, and MAUT methods to compare the STI capabilities of 40 countries. Jian [2] applied the VHSD-EM model to evaluate the high-quality development and digital innovation of the shipping industry in 11 Chinese coastal provinces.

(3) Evaluation of subjective and objective weight combination assignment

Qiu [5] constructed a framework for identifying and evaluating disruptive technologies in smart cities using the entropy weighting and hierarchical analysis methods, and verified the feasibility and validity of the proposed framework. Zhang [9] combined FAHP and BP neural networks to evaluate the fuzzy adaptive efficiency of the open sharing platform of scientific and technological resources. The results showed the accuracy and reliability of the constructed model. Yang [7] used the comprehensive weight method based on entropy measurement and DEMATEL to measure the weights of evaluation indexes to assess the STI capability.

The analysis of the existing literature revealed that scholars mainly adopted a single subjective or objective empowerment method for evaluating regional STI capability. Not many studies used the subjective empowerment method combined with the objective empowerment method, and the AHP method could not combine the scores of multiple experts into a judgment matrix. Meanwhile, most scholars examined the data of a single region or a single year for regional STI capability assessment, and few scholars combined multiple regions and multiple years.

To address the aforementioned problems, this study was based on the cluster AHP–entropy weighting method to dynamically evaluate the level of STI capability of 12 leagues and cities in Inner Mongolia, better reflecting the development status of STI of each league and city over the years.

The marginal contributions of this study were as follows. (1) The cluster AHP method was combined with the entropy weighting method to realize the unification of the objective law of data and the cognitive experience of experts, making up for the drawbacks of the existing studies that adopted a single subjective or objective method for measuring the weights. This approach led to the degree of data variation or the experience of experts not reflecting the degree of data variance. (2) Different weights were assigned to different years to reflect the dynamic characteristics of the time dimension "the more recent the more important" in evaluating STI, addressing limitations in previous studies. This approach failed to reflect the importance of time in evaluating STI.

Dynamic Evaluation Principles of STI in Inner Mongolia under the Combined Empowerment of Cluster AHP-Entropy Weighting Method

(1) Difficulties of the dynamic evaluation of STI in Inner Mongolia

The weights of the indicators of each year in the indicator system of the STI capability of Inner Mongolia from 2016 to 2020 were dynamically assigned using the cluster AHP–entropy weighting method to reflect the developmental trend of regional STI in Inner Mongolia in recent years.

(2) Solutions to difficulties

This study dynamically assigned the indicator weights of each year in the indicator system of STI capability of Inner Mongolia using the cluster AHP–entropy weighting method under the time weighting of the static combination weights of each year in each city of Inner Mongolia.

Principle of determining indicator weights based on the cluster AHP method:First, a new matrix with the same number of rows as the original matrix was built, the eigenvectors of each column of each newly constructed matrix were calculated, and the average value of the eigenvectors of the matrix was determined as a single weight assigned by each expert to each indicator. Afterward, the newly constructed judgment matrix coefficients based on expert assignment were calculated, and the judgment matrix coefficients of each expert were summed up. Finally, the percentage of each expert's judgment matrix coefficients in the total sum was used as the indicator's subjective final assignment weights.

Principle of determining the objective weights of the indicators using the entropy weighting method:The entropy weighting method assigned objective weights to each indicator, and the calculated weights of the indicators were used to judge the extent of difference between the indicators in the evaluation system of STI. First, based on the standardized data, we calculated the weight of the ith indicator under the jth system of the evaluation system of STI in the proportion of the indicator. Then, we calculated the entropy value of the jth system under the evaluation system. Further, we calculated the coefficient of variability and determined the objective weights of each indicator of the system of STI.

Static combination weights of indicators for the cluster AHP–entropy weighting method:Given a certain degree of subjectivity in the cluster AHP method, the subjective weight W_i calculated using the assigned cluster AHP was 0.4 in the combination weight, and the objective weight W_j^* calculated using the entropy weight method was 0.6 in the combination weight. Then, the subjective and objective weights were multiplied by their respective percentage coefficients in the combination weight and then summed up as the static combination weights.

Determination of the time-weighted vector:The closer the time to the current year, the more significant the influence of the data on the evaluation system of STI, and the farther the time from the current year, the less the influence of the data on the evaluation system of STI; through the different time leads to the different degree of significance to the evaluation system and reflect the evaluation system's characteristics of the time dimension. Therefore, the maximum entropy model was applied to weigh the static portfolio weights of the indicators of the evaluation system of STI of each league and city in Inner Mongolia in the previous years.

Principle of dynamic composite weighting of indicators by combined assignment of cluster AHP–entropy weighting methods:The static combination weights of the indicators were time-weighted into dynamic composite weights using a time-weighted vector.

Principle of static score calculation:The standardized data for 2016–2020 were multiplied by the dynamic composite weights based on a combination of subjective and objective weights to provide a static score for STI for each city in Inner Mongolia.

The principle of the dynamic evaluation model of STI in Inner Mongolia based on group cluster AHP-entropy weighting method is shown in Figure 1.

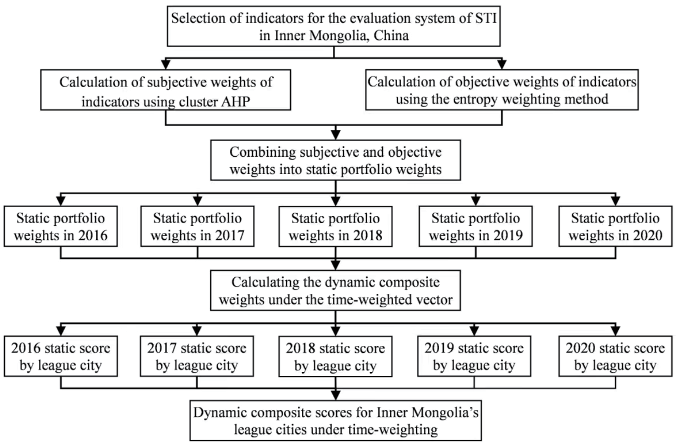

Figure 1. Technology roadmap for the evaluation of STI in Inner Mongolia.

2. Dynamic evaluation method of STI in inner Mongolia under the combined empowerment of cluster AHP-entropy weighting method

2.1. **Identification of subjective weights of indicators based on the cluster AHP approach.**

As the subjective weights are based on the scoring by experts, the more significant indicators cannot be ignored. The AHP method is a subjective assignment method used to determine the weights of indicators by comparing and scoring each element, which has the advantages of strong operability and wide applicability compared with other subjective assignment methods. Therefore, this study adopted the AHP method to determine the subjective weights of indicators. Moreover, the AHP method is used for scoring by multiple experts, and hence multiple judgment matrices are formed. However, the existing AHP method does not clearly state the calculation method of the final weights of all indicators scored by multiple experts. Therefore, this study used the cluster AHP method to form a reasonable final judgment matrix by assigning different weight coefficients to the experts according to their varying experiences.

First, four experts with different experiences were invited to grade the significance of the elements in the criterion and goal layers using the 1–9 scale method to reduce subjectivity so that the different weighting factors assigned to the four experts were 1.0, 1.0, 0.9, and 0.9, respectively.

The specific algorithm of the cluster AHP method was to calculate the improved algorithm of indicator weights based on the consistency-based scoring matrix for a single expert and then apply the cluster AHP approach to compute the final weights of multiple experts for all indicators in the criterion and indicator layers.

(1) Improved algorithm for calculating indicator weights for a single expert's scoring matrix

i) Let the original expert scoring matrix be A. The qth row of the original expert scoring matrix A was used to construct a new consistency matrix $A^{(q)}$:

$$A^{(q)} = \begin{bmatrix} \frac{a_{q1}}{a_{q1}} & \frac{a_{q2}}{a_{q1}} & \cdots & \frac{a_{qn}}{a_{q1}} \\ \frac{a_{q1}}{a_{q2}} & \frac{a_{q2}}{a_{q2}} & \cdots & \frac{a_{qn}}{a_{q2}} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{a_{q1}}{a_{qn}} & \frac{a_{q2}}{a_{qn}} & \cdots & \frac{a_{qn}}{a_{qn}} \end{bmatrix}.$$

ii) All the elements of the jth column of the $A^{(q)}$ were summed up, and each element of the jth column was divided by adding up the elements of the jth column to obtain the eigenvector of the consistency matrix $\Phi^{(q)}$.

$$\phi^{(q)} = \frac{a_{q1}}{\sum\limits_{j=1} (a_{qj})}. \tag{2.1}$$

iii) Let the eigenvector of the consistency matrix of each expert be $\varphi_n^{(q)}$.

$$\varphi^{(q)} = (\varphi_1^{(q)}, \varphi_2^{(q)}, \ldots, \varphi_n^{(q)}). \tag{2.2}$$

iv) Let the average of the newly computed consistency matrix eigenvectors for each expert be $a_i^{(q)}$, where j denotes each column of each consistency matrix:

$$a_i^{(q)} = \frac{1}{n} \sum_{j=1}^{n} \sum \varphi_j^{(q)}. \tag{2.3}$$

v) Let the weight of each indicator be a_n, and then the weight of the index based on the scoring matrix of each expert is:

$$a = (a_1, a_2, \ldots, a_n). \tag{2.4}$$

(2) The cluster AHP method was used to compute the final weights of indicators

Assuming that the weight coefficients of each expert are λ_1, λ_2,..., λ_s; the final indicator weights for the n indicators R_1, $R_2 \ldots$, R_n were calculated as follows:

i) The weights of the indicators for each judgment matrix A_q were set to be $a^{(q)}$:

$$a^{(q)} = (a_1^{(q)}, a_2^{(q)}, \ldots, a_n^{(q)}). \tag{2.5}$$

ii) Let be β_i the newly constructed judgment matrix coefficients based on the expert weight coefficients, where s is the number of experts:

$$\beta_i = \prod_{q=1}^{s} [(a_i^{(q)})^{\lambda_j}]. \tag{2.6}$$

The role of equation (2.6) is: to reflect the more accurate judgment matrix coefficients under the larger weight coefficients assigned to experienced experts.

iii) Let β be the sum of the total coefficients of the newly constructed judgment matrix coefficients under the expert weight coefficients:

$$\beta = \sum_{i=1}^{n} \beta_i. \tag{2.7}$$

iv) Let W_i be the weight of each indicator within the indicator layer:

$$W_i = \frac{\beta_i}{\beta}. \tag{2.8}$$

v) Let the final indicator weights of n elements R_1, $\mathrm{R}_2 \ldots$, R_n of this target or indicator layer be W_i:

$$W_i = (W_1, W_2, \ldots, W_n). \tag{2.9}$$

2.2. **Determination of objective weights of evaluation indicators using the entropy weighting method.**

Entropy is the average amount of information; the larger the amount of information, the smaller the corresponding entropy value. The use of the entropy weighting method to evaluate the objective weighting of indicators can better reflect the idea of "the larger the information content of the evaluation of the indicators to give the greater weight" of the assignment compared with other methods. The steps for determining the objective weights of the evaluation indicators using the entropy weighting method are as follows:

(1)Standardization of indicators

Setting X_{ij} as the degree of affiliation of the jth indicator of the ith evaluated alliance, V_{ij} as the value of the jth indicator of the ith evaluated alliance, and n as the total number of alliances; the positive indicator X_{ij} was calculated as follows:

$$X_{ij} = \frac{V_{ij} - \min\limits_{1\leqslant i\leqslant n}(V_{ij})}{\max\limits_{1\leqslant i\leqslant n}(V_{ij}) - \min\limits_{1\leqslant i\leqslant n}(V_{ij})}. \tag{2.10}$$

(2) Computation of the dedication degree f_{ij}, entropy value e_j, and coefficient of variation g_j for each indicator

Let f_{ij} be the weight of the ith league under the jth indicator; e_j be the entropy value of the jth index; g_j be the coefficient of variation; f_{ij} is the weight of the jth indicator in the ith system,and X_{ij} be the data of the jth indicator in the ith system (i=1, 2,...,n; j=1,2,...,m),then

$$f_{ij} = \frac{X_{ij}}{\sum\limits_{i=1}^{n} X_{ij}}, \tag{2.11}$$

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} f_{ij} \ln (f_{ij}). \tag{2.12}$$

The effect of equation (2.12):is to calculate the degree of divergence of each indicator because the more the dispersion of an indicator, the greater the influence of the indicator on the evaluation system of STI in Inner Mongolia.

$$g_j = 1 - e_j. \tag{2.13}$$

(3) The objective weight of each indicator W_j^* was calculated as follows:

$$W_j^* = \frac{g_j}{\sum\limits_{j=1}^{m} g_j}. \tag{2.14}$$

2.3. **Dynamic composite weights under time-based weighted vectors.**

(1) Static combination weights of indicators for the cluster AHP-entropy weighting approach

Let W_i be the static subjective weight of the indicators and W_j^* be the static objective weight of the indicators. Because of a certain degree of subjectivity in the cluster AHP method, the subjective weight W_i calculated by the assigned cluster AHP had a proportion of 0.4 in the combination weight and the objective weight W_j^* calculated by the entropy weight method had a proportion of 0.6 in the combination weight; W_{zn}^t was set as the static combination weight, expressed as:

$$W_{zn}^t = 0.4 \cdot W_i + 0.6 \cdot W_j^*. \tag{2.15}$$

(2) Determination of the time-weighted vector

The time-weighted vector is calculated as follows [6]:

$$\left[\begin{array}{l} \max \left(-\sum\limits_{t=1}^{T} w_t \ln w_t \right) \\ \lambda = \sum\limits_{t=1}^{T} \frac{T-t}{T-1} w_t \end{array}\right. . \tag{2.16}$$

Where w_t is the vector of temporal weights for different years under the maximum entropy model, t = 1, 2..., n; λ is the degree of importance to the time vector; the overall number of evaluation years is set to T; and t is the tth evaluation year.The role of equation (2.16) is to reflect the time dimension characterizing STI evaluation.

(3) Calculation of dynamic composite weights W_{Dn}

$$W_{Dn} = \sum_{t=1}^{T} W_{Zn}^{t} \cdot w_t. \tag{2.17}$$

2.4. **Calculation of the score.**

(1)Calculating the static score p_j

$$p_j = MMULT(F_{ij} \cdot W_{Dn}). \tag{2.18}$$

Where F_{ij} is the standardized score of each indicator and W_{Dn} is the dynamic composite weight of each indicator.

(2) Calculating the dynamic composite score P_m.Where p_j is the static score; w_t is the time weight.

$$P_m = \sum_{t=1}^{T} p_j \times w_t. \tag{2.19}$$

3. Empirical analysis of comprehensive dynamic evaluation

3.1. **Indicator system and sources of data.**

The original data of the indicators were obtained from the statistical yearbook of Inner Mongolia for the years 2017–2021 and the statistical yearbooks of 12 leagues and cities. The indicators were standardized and scored according to the types of indicators. The index system used and the raw and standardized data are shown in Table 1.

Table 1. Indicator system for evaluating STI in Inner Mongolia, raw data for each indicator for 2016–2020, and standardized data

No.	(1)Standardised layer	(2)System of indicators	Raw Data 2016-2020			Standardized data 2016-2020		
			(3)Hohhot	…	(62)Alxa	(63)Hohhot	…	(122) Alxa
1		X_1 Internal expenditure on STI as a share of fiscal expenditure	2.53%	…	0.48%	1.000	…	0.905
2	Scientific and technological environment	X_2 R & D expenditures as a share of GDP	0.24%	…	0.03%	1.000	…	1.000
3		X_3 per capita gross domestic product	106.70	…	11.66	0.188	…	0.343
…	…	…	…	…	…	…	…	…
13		X_{13} Share of local universities in total published scientific papers	0.83	…	17.00	1.000	…	1.000
…	Scientific and technological outputs	…	…	…	…	…	…	…
16		X_{16} Number of scientific and technological progress awards	63.00	…	1.00	1.000	…	1.000

3.2. **Determining indicator weights for cluster AHP.**

First, the expert used the 1–9 scale method according to the judgment matrix scale to compare all the indicators within the indicator layer two by two to construct the judgment matrix, and then according to equations (2.1)–(2.9) to calculate the subjective weights of the indicators using the cluster AHP method, to get the final weight W_i of the indicators included in the second column of Table 2. After calculating the final subjective weights of each indicator, the normalization was performed. The normalized subjective weights are listed in column 3 of Table 2.

3.3. Calculation of indicator weights for the indicator layer based on the entropy weighting method.

First, the raw data of each indicator were substituted into equation (2.10) for standardization. Then the standardized indicator data were substituted into equations (2.11)–(2.14) to calculate the objective weights of the indicators from 2016 to 2020, which are included in columns 4–8 of Table 2.

TABLE 2. Subjective weights under cluster AHP and entropy weights under entropy weighting method for each year W_j^*

No.	(1)Indicator	Subjective weighting under the cluster AHP		Entropy rights 2016-2020W_j^*				
		(2)Subjective weights	(3)Normalized	(4)2016	(5)2017	(6)2018	(7)2019	(8)2020
1	X_1	0.146	0.029	0.070	0.124	0.056	0.064	0.035
2	X_2	0.478	0.096	0.022	0.123	0.021	0.033	0.034
...	...	...	...	...	...	...	...	...
15	X_{15}	0.385	0.077	0..072	0.059	0.044	0.086	0.077
16	X_{16}	0.258	0.052	0.063	0.048	0.072	0.052	0.069

3.4. Determination of STI evaluation in each union city.

First, according to equation (2.15), the static combined weights W_{zn}^t of each indicator for 2016–2020 were obtained and included in columns 1–5 of Table 3. Second, the time weights were determined by taking λ to be 0.1 and n to be 5 and substituting them into equation (2.16) to obtain the time-weighted vector for 2016–2020 as 0.005, 0.018, 0.060, 0.207, and 0.710, respectively. Then, the W_{zn}^t and the time weights were substituted into equation (2.17) to calculate the dynamic combined weights, which is included in column 6 of Table 3. Finally, the static and dynamic composite scores of STI of each union city were calculated according to equations (2.18) and (2.19), respectively; the final results are shown in Table 4.

TABLE 3. Static portfolio weights and dynamic, comprehensive weights from 2016 to 2020

No.	2016-2020 static portfolio weights					(6) Dynamic composite weights	(7)Ranking
	(1)2016	(2)2017	(3)2018	(4)2019	(5)2020		
X_1	0.054	0.086	0.045	0.050	0.033	0.038	16
X_2	0.051	0.112	0.051	0.057	0.059	0.059	9
...	...	...	...	...	...	...	...
X_{15}	0.074	0.066	0.057	0.083	0.077	0.077	5
X_{16}	0.058	0.049	0.064	0.052	0.062	0.060	8

Table 4. Static and dynamic scores and ranking of each league city from 2016 to 2020

No.	(1) League	Static scores of each league city from 2016 to 2020					(7)Dynamic composite score	(8)Final Ranking	(9) Time-weighting Entropy weighting method of ranking
		(2)2016	(3)2017	(4)2018	(5)2019	(6)2020			
1	Hohhot	0.753	0.535	0.725	0.818	0.852	83.18	1	1
2	Baotou	0.271	0.241	0.300	0.291	0.352	31.96	2	2
...	...	...	...	...	...	...	...	...	...
11	Wuhai	0.192	0.135	0.207	0.143	0.201	18.07	4	4
12	Alxa	0.073	0.388	0.056	0.113	0.101	10.47	8	8

This study used SPSS to analyze the marks of 12 leagues through K-mean clustering, divided into three echelons. The results are displayed in Table 5.

Table 5. Results of cluster analysis of the comprehensive score of STI dynamics in each league

No.	(1)12 Leagues	(2)Cluster analysis results
1	Hohhot	The first echelon
2	Baotou	The second echelon
3	Erdos	
4	Wuhai	
5	Hulunbeier	The third echelon
...	...	
12	Hinggan	

3.5. **Empirical findings.**

The conclusions based on the aforementioned empirical findings were as follows. First, according to the dynamic comprehensive weights of the evaluation system of STI in Inner Mongolia, four indicators, including the turnover of technology contracts, were the most important factors affecting the regional STI capability of Inner Mongolia. From the economic point of view, the main reason for the unbalanced development of STI capability in Inner Mongolia's allied cities was that these indicators were unevenly developed in each region. Therefore, if we want to promote further the balanced development of STI capability in each city, we need to promote the balanced development of the economy of each city.

Second, Hohhot is the only league with an overall score of 80 points or more for the dynamics of STI, whereas the lowest score is for Xing'anmeng, with a score of only 3.18 points. From an economic perspective, Hohhot's high overall score on STI dynamics is related to its advantages in economic development, resource allocation, and policy support as the capital of Inner Mongolia. In contrast, the lower scores of Xing'anmeng, Ulanqab, and other regions have issues such as a weak economic base, a lack of resources, and a shortage of talent.

4. Comparative analysis and policy recommendations

A comparative analysis was conducted from the perspective of the ranking of leagues and cities under the assignment of different weights to verify that the results of the dynamic evaluation of STI in Inner Mongolia's leagues and cities had stability. The ranking of leagues and cities under the time-weighted entropy weighting method is shown in the ninth column of Table 4. As displayed in columns 8 and 9 of Table 4, the rankings of all the alliance cities using the two assignment methods were completely consistent. Therefore, it was considered that the evaluation results of the dynamics of STI of all the alliance cities in Inner Mongolia were stable.

First,the geographical cooperation as well as the resource-sharing capability of STI innovation in all leagues an cities of Inner Mongolia should be strengthened. In the current context of regional innovation integration construction, promoting the synergistic development of scientific and technological innovation capability among the regions of Inner Mongolia and intensifying the sharing of scientific and technological resources among the 12 Inner Mongolia cities are highly indispensable for the development of Inner Mongolia's economy. At the same time, leagues with strong STI capabilities should demonstrate leadership by sharing successful practices in scientific and technological innovation. This would provide valuable reference experiences for leagues with insufficient STI capacity, enabling various leagues and cities in Inner Mongolia to complement and share STI resources. This goal is to gradually reduce disparities in STI capacity across Inner Mongolia's leagues and cities.

Second, we should not only promote the STI capability among allied cities in Inner Mongolia but also focus on further improvement of the overall economic development capacity of Inner Mongolia because the STI capacity is closely linked to the overall level of economic development of league cities. For those municipalities that do not maintain a dynamic balance in the development of regional STI capability, the municipal governments of Inner Mongolia should take effective countermeasures to significantly increase the overall level of economic development of the municipalities to facilitate the enhancement of STI capability.

5. Conclusions

(1) This study empowered the 2016–2020 STI evaluation index system for 12 cities in Inner Mongolia using the subjective–objective cluster AHP-entropy weighting method. The cluster AHP approach formed a scoring matrix by aggregating scores from multiple experts, capturing expert experience, while the entropy weight method ensured objectivity. The combined approach adequately integrated expert insights and actual objective data. The characteristics of this study were as follows. 1) It realized the unification of the objective law of data and the cognitive experience of experts by combining the cluster AHP method with the entropy weighting method. This made up for the drawbacks of the existing studies that adopted a single subjective or objective method for measuring weights, which led to the degree of data variation or the experience of experts not being able to reflect the degree of data variance. 2) The dynamic characteristics of the time dimension "the more important the nearer the time is" were reflected in the evaluation of STI by assigning different weights to different years.

(2) The empirical results showed that the score of the dynamics of STI in Inner Mongolia was divided into three echelons through K-mean cluster analysis. The first echelon contained only Hohhot; the second echelon contained three cities: Baotou, Ordos, and Wuhai; and the third echelon contained eight cities. The level of STI in the three echelons of the cities varied a lot. The empirical results revealed that the STI capability was relatively strong in moredeveloped cities of Inner Mongolia.

The overall evaluation results showed that Hohhot, Baotou, and Ordos were more developed with strong STI capability. Also, in the eastern region of Inner Mongolia, the four cities were in the third echelon of the economic level and hence their STI capability needed to be improved.

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