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Evaluation of the Health Status of the National Higher Education System Based on Mathematical Model

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Abstract: *In order to measure and evaluate the health status of the higher education system at the national level, first,select index factors that can reflect the level of higher education in the country, and establish an entropy weight-weighted Topsis comprehensive evaluation model, which is measured by the comprehensive evaluation index and the index factor weight ratio The level of higher education in the country. At the same time, in order to measure the sustainable state of the national higher education system, taking China as an example,by constructing a prediction model based on MLP multilayer perceptron, combined with an evaluation model, predicting the country's education level in the next few years. Finally, policy recommendations are made on the health and sustainability of the national higher education system.*

Keywords: *entropy weight-weighted Topsis, MLP multilayer perceptron, higher education system, health status*

1. Introduction

The health of the higher education system is closely related to the state of the country's economic and social development, and also affects each other. In order to ensure the sustainable development of the system, under the epidemic situation, governments of all countries should investigate the shortcomings of their higher education system carefully, actively discover their own advantages, make use of their strengths, promote and implement effective policies, and help the country to Healthy and sustainable development.

In the research on the evaluation of higher education systems in developed countries, taking the United States as an example, Xu Limin [1] (2006) proposed that the US Council for Higher Education is a non-governmental organization, which is different from the US Department of Education (government agency). The relationship between the two is guaranteed The unique advantages of the American higher education system. Thanks to this partnership, the evaluation criteria of the American higher education system are not single. Huang Huijuan [2] (2005) pointed out that the American higher education quality assurance system has a long history, its higher education certification system is closely in line with international standards, and its government functions are unique, and it has an independent, non-profit educational evaluation agency.

In terms of research on the evaluation of higher education systems in developing countries, taking China as an example, Wang Lili et al. [3] (2012) took Qingdao University of Science and Technology as an example, and proposed that the construction of a higher education evaluation system should pay attention to the core links of education and shift its focus downward. Carry out lower-level evaluations to achieve normalization and three-dimensional evaluation. Xu Weiwei [4] (2007) proposed that to build a healthy higher education quality evaluation system, attention should be paid to hierarchy, evaluation from micro to macro, combined with the daily education and teaching process of colleges and universities, and to pay attention to and guarantee the quality of education.

Combining the above related research,this paper adopts the entropy weight-weighted Topsis comprehensive evaluation model to evaluate the higher education level of various countries, and adopts the prediction model based on the MLP multilayer perceptron to predict the country’s future education level,so as to provide the country with relevant education reform Policy Support.

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2. Data sources and research methods

2.1 Data source

In order to evaluate the higher education systems of multiple countries[5], considering the differences in geographic locations between developed and developing countries, China, Japan, France, Poland, Mexico, the United States, and China were selected from the statistical yearbooks of each country from 2009 to 2019. The indicator data of nine representative countries in Argentina, Australia, and New Zealand. Among them, indicators are selected from the aspects of education cost, educational opportunities, teaching quality, etc[6]. Finally, eight indicators are selected, namely, the number of graduates from higher education and ordinary higher education institutions. The number of students in school, the population of the right age for higher education, the gross enrollment rate of higher education, the proportion of college students in higher education, the proportion of government education expenditure in GDP, the total number of overseas students, and the teacher-student ratio of higher education[7].

2.2 Data processing

Using factor analysis, the data in the above eight dimensions of the data in the above eight dimensions in China, Japan, France, Poland, Mexico, the United States, Argentina, Australia, and New Zealand from 2006 to 2016 were reduced.

According to Table 1, the variance explanation rates of the first four factors are 56.891%, 20.553%, 9.900%, 6.631%, and the total variance explanation rate is 93.976%.

Table 1 Explanation table of total variance

Total variance explained			
ingredient	Initial eigenvalue		
	total	Variance%	Cumulative%
1	4.551	56.891	56.891
2	1.644	20.553	77.445
3	.792	9.900	87.345
4	.530	6.631	93.976
5	.363	4.541	98.517
6	.078	.980	99.497
7	.038	.471	99.968
8	.003	.032	100.000

From the rotated component matrix and component scoring coefficient matrix in Table 2, the influencing factors included in each component and the proportional relationship with the component are obtained. The complete data dimensionality reduction processing results are shown in Table 3.

Table 2 Component matrix after rotation

	ingredient			
	1	2	3	4
Zscore(gra)	.973	.126	-.006	-.018
Zscore(edu)	.951	-.075	-.070	.062
Zscore(age)	.935	-.229	.042	-.135
Zscore(ent)	-.377	.320	.281	.755
Zscore(jun)	.658	-.125	-.075	.634
Zscore(exp)	.207	.942	.206	.116
Zscore(abr)	.955	-.161	.076	-.134
Zscore(tea)	.055	.186	.971	.110

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Table 3 Data dimensionality reduction processing results

Original influencing factors	Belonging factor	Single factor score function	Factor interpretation rate	Rank
x_1	Number of teachers factor F1	$f_1 = 0.254x_1 + 0.264x_2 + 0.213x_3 + 0.236x_7$	56.891	1
x_2				
x_3				
x_4				
x_5	Education cost factor F2	$f_2 = 1.133x_6$	20.553	2
x_6	Teaching quality factor F3	$f_3 = 1.016x_8$	9.900	3
x_7	Educational Opportunity Factor F4	$f_4 = 0.708x_4 + 0.717x_5$	6.631	4
x_8				

Finally, according to the single factor score function, the single factor scores of nine countries in China, Japan, France, Poland, Mexico, the United States, Argentina, Australia, and New Zealand are calculated. Evaluation.

2.3 Research methods

2.3.1 Entropy weight-weighted Topsis comprehensive evaluation model

The traditional methods for determining index weights include analytic hierarchy process and expert scoring method. Due to its strong subjectivity and randomness, we choose entropy weight method to determine index weights to improve the objectivity of the weights. The specific entropy method steps are as follows:

Step1: Suppose the number of indicators for evaluating the higher education system is m, the number of each indicator is n, and finally a country's evaluation system is established as a matrix:

$$X = (x_{ij})_{m*n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step2: Calculate the entropy value of each indicator, the entropy value of the indicator i is:

$$L_j = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ij} \ln f_{ij} \quad (2)$$

$$f_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (3)$$

Step3: Calculate the entropy weight of each indicator, the entropy weight of the indicator j is:

$$w_j = \frac{1-L_j}{m-\sum_{j=1}^{m} L_j} \quad (4)$$

Get the index entropy weight vector $w = (w_1, w_2, \cdots, w_m)$.

After determining the index weights according to the above-mentioned entropy method, we use the weighted Topsis[8] comprehensive evaluation method to score each index to reflect the health and sustainability of the national higher education system. The specific steps are as follows:

Step1: Use the vector programming method to obtain the standard decision matrix. Suppose the decision matrix of the multi-attribute decision-making problem $A = (a_{ij})_{m*n}$, the standardized decision matrix $B = (b_{ij})_{m*n}$, among them:

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad i = 1,2,\cdots,m, j = 1,\cdots,n \quad (5)$$

It can also be transformed into a normalized matrix through the standard 0-1. In order to make the optimal value of each attribute transformed to 1 and its worst value to 0, we use the following method to normalize the matrix.

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If x_j is a benefit attribute, then:

$$b_{ij} = \frac{a_{ij}-a_j^{min}}{a_j^{max}-a_j^{min}} \tag{6}$$

If x_j is a cost attribute, then:

$$b_{ij} = \frac{a_j^{max}-a_{ij}}{a_j^{max}-a_j^{min}} \tag{7}$$

Step2: Form a weighted norm matrix $C = (c_{ij})_{m*n}$, and the weight $[w_1, w_2, \cdots w_n]^T$calculated according to the above entropy weight method, then $c_{ij} = w_j * b_{ij}, i = 1,2, \cdots m, j = 1 \cdots n$.

Step3: Determine the positive ideal solution and the negative ideal solution and determine the distance from each plan to the positive and negative ideal solution. Suppose the first attribute value of the positive ideal solution is, and the first attribute value of the negative ideal solution. The distance from the alternative to the positive ideal solution is:

$$s_i^* = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^*)^2} \qquad i = 1 \cdots m \tag{8}$$

The distance from the alternative to the negative ideal solution d_i is:

$$s_i^0 = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^0)^2} \qquad i = 1 \cdots m \tag{9}$$

Step 4: Calculate the queuing index value of each scheme (ie comprehensive evaluation index):

$$f_i^* = \frac{s_i^0}{s_i^0+s_i^*} \qquad i = 1 \cdots m \tag{10}$$

2.3.2 Predictive model of MLP multilayer perceptron

Multilayer perceptron (MLP) is a supervised learning algorithm involving deep learning[9]. The MLP algorithm can be regarded as an algorithm in which a generalized linear model is processed in multiple layers[10]. The mathematical formula of the generalized linear model:

$$\hat{y} = w[0] * x[0] + w[1] * x[1] + \cdots + w[p] * x[p] \tag{11}$$

Among them $w[i]$ is the weight coefficient, $w[0]$is the intercept term b, $x[0] = 1$, pis the number of features.

It is essentially a hierarchical network structure composed of multiple neurons[11]. For example, a multilayer perceptron with a three-layer network structure looks like this:

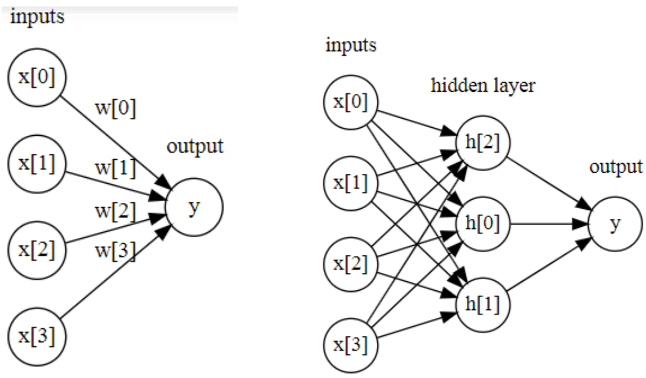

Figure 1 Schematic diagram of multilayer perceptron

Figure 1 shows the structure of a multilayer perceptron model with a three-layer neuron structure. Among them, the middle layer of neurons is called the hidden layer. Take a look at the mathematical expressions of each neuron on the hidden layer:

$$\begin{aligned} h[0] &= w[0][0] * x[0] + w[1][0] * x[1] + w[2][0] * x[2] + w[3][0] * x[3] \\ h[1] &= w[0][1] * x[0] + w[1][1] * x[1] + w[2][1] * x[2] + w[3][1] * x[3] \\ h[2] &= w[0][2] * x[0] + w[1][2] * x[1] + w[2][2] * x[2] + w[3][2] * x[3] \end{aligned} \tag{12}$$

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The w[x][y] in the formula represents the weight coefficient from the xth neuron on the previous layer of neurons to the yth neuron in this layer. For example, w[0][0] represents the weight coefficient value from the 0th neuron of the 0th layer (input layer) to the 0th neuron of this layer (hidden layer), and so on.

3. Evaluation of the national higher education system based on the entropy weight-weighted Topsis comprehensive evaluation model

Using the method of entropy-weighted Topsis comprehensive evaluation model, and the index data of 9 representative countries after dimensionality reduction, using MATLAB, the comprehensive evaluation index of each index of each country is calculated. The specific results are shown in the figure below.

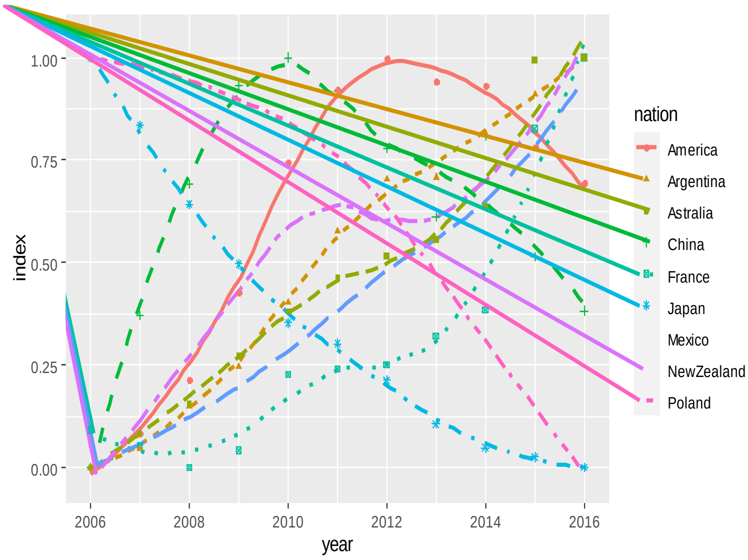

Figure 2 Comprehensive evaluation index map of countries

As can be seen from the above figure, according to the comprehensive evaluation index of each country, the health status of the higher education system of each country can be judged. Among them, the countries that have room for improvement to a certain extent are the United States, China, Poland, and Japan.

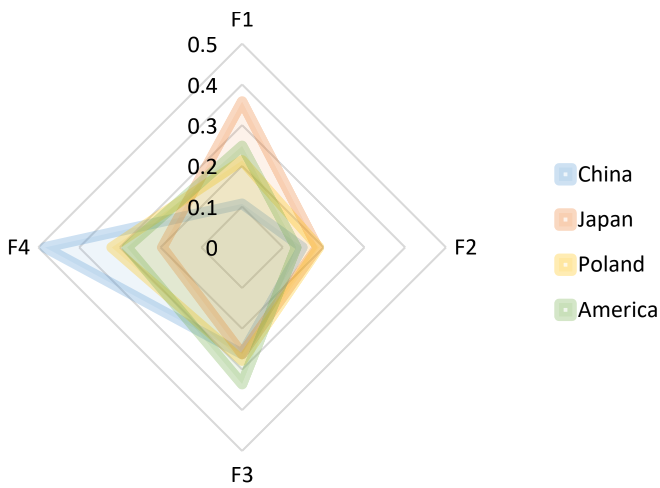

Figure 3 Comparison of countries with room for improvement

Figure 3 shows the weight ratios of the four index factors of the higher education system in the United States, China, Poland, and Japan from 2009 to 2019, where F1 represents the number of teachers, F2 represents the education cost factor, F3 represents the teaching quality factor, F4 stands for the opportunity factor of being taught. From the weight ratios of these index factors, we can see that the four countries have room for improvement to a certain extent. We need to find the reasons from the

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index factors with different weights. The specific indicators are biased in Table 4. For example, in China, the education system focuses on F4. Ignoring F1 and F2, we need to pay more attention to some F1 and F2 in the next few years to make improvements.

Table 4 The indicators of various countries are biased

Countries	Partiality	Ignore
United States	F3	F2
China	F4	F1,F2
Poland	F4	F1
Japan	F1	F2,F4

4. Predictive model based on MLP multilayer perceptron

In order to analyze the education level of countries in the next few years if they do not intervene under the existing education system, a predictive model based on MLP multilayer perceptron is constructed. Taking China as an example, the R language is used to determine the overall level of China. After analyzing the MLP algorithm, a multi-layer perceptron model with 2 hidden layers and 6 neurons in each layer is constructed.

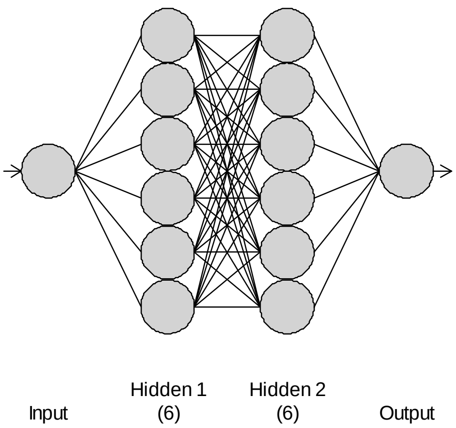

Figure 4 China MLP map

Through the multi-layer perceptron model, based on the original data, we predict the number of teachers, the education cost factor, the teaching quality factor, and the teaching opportunity factor of the education system indicators in the next 10 years, and the results are as follows:

Table 5 China's Four Factors Forecast Table

year	F1	F2	F3	F4
2020	16327018	5.69175	18.39727	64.94289
2021	16200521	5.868109	18.75725	65.88196
2022	13312184	5.999907	18.15355	66.78578
2023	13602703	6.175222	18.19729	67.70938
2024	11884696	6.389486	18.11557	68.63293
2025	11734649	6.626327	17.90358	69.55894
2026	10602122	6.808062	18.18483	70.48525
2027	10004652	6.981152	18.54916	71.41191
2028	9069155	7.168845	18.18926	72.33865
2029	8304091	7.377206	18.53668	73.26545

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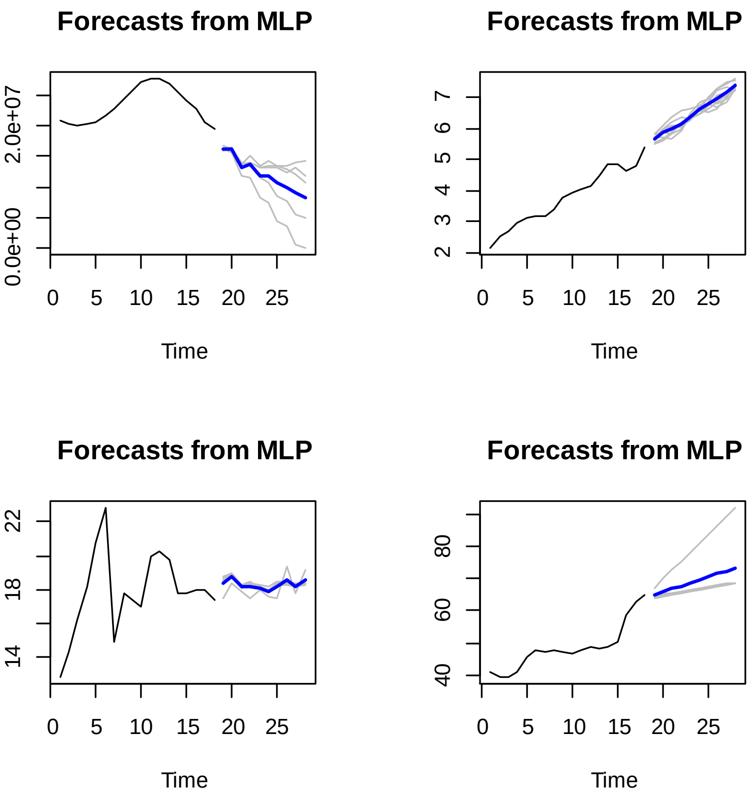

Figure 5 China's four major indicators forecast

It is predicted that in the next five years, the development of the number of teachers will decline slightly, the level of the teaching quality factor will remain unchanged and there will be minor fluctuations, while the education cost factor and the teaching opportunity factor will increase significantly. Among the reasons for this result may be the opening of the second-child policy and the implementation of a series of educational measures.

Through the predicted data of the four major indicators in China, substituting the entropy weight-weighted Topsis comprehensive evaluation model, a comprehensive evaluation index that can reflect the sustainability of China is finally obtained, as shown in the figure below.

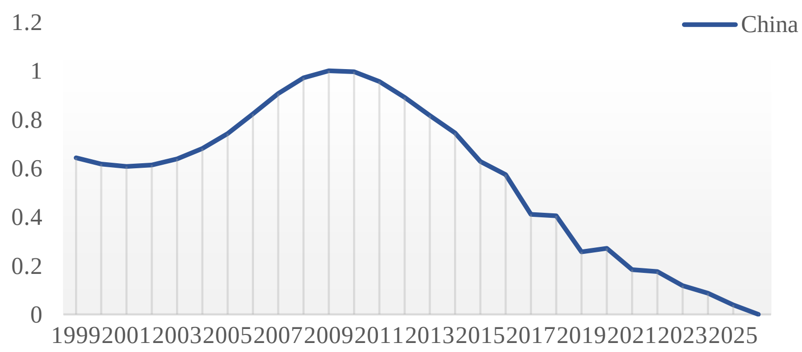

Figure 6 Evaluation index map of China's higher education system

As can be seen from the above figure, from 2009 to 2026, the comprehensive evaluation index of China's higher education system has shown a downward trend, which shows that if there is no intervention, the health of China's higher education system and sustainability status will gradually decrease.

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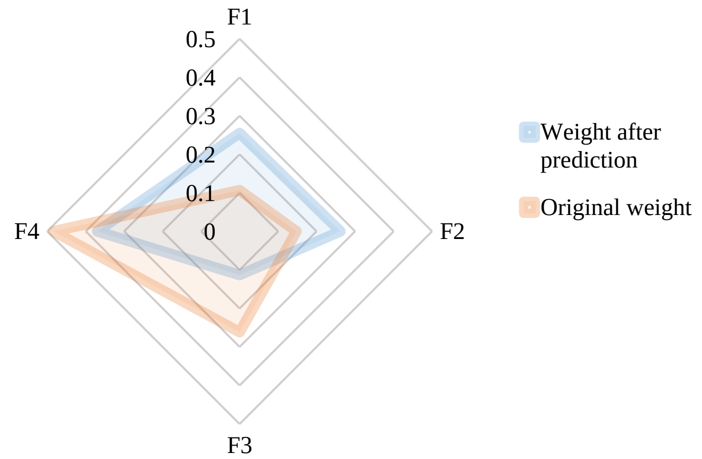

Figure 7 Comparison of the weights of China's four indicators before and after

Figure 7 reflects the indicator weight ratio of China's current higher education system and the indicator weight ratio of the higher education system in the next few years without intervention. Judging from the current index weight ratio, China places more emphasis on the F4 education opportunity factor. Without intervention, China will gradually balance the four factors, but in the end it will show contempt for the F3 teaching quality factor, which is also in line with the actual situation in China. Consistent with the continuous development of society, China's higher education system pays more and more attention to the number of other educators, the number of teachers, and the educational opportunities of students, while often neglecting the quality of education. In other words, if China does not implement certain Measures will lead to a continuous decline in the level of the higher education system.

5. Conclusions and recommendations

Through the construction of an entropy weight-weighted Topsis comprehensive evaluation model, the health status of higher education systems in various countries can be effectively measured. At the same time, the higher education systems of the United States, China, Japan, and Poland, among the nine representative countries selected in the article, are to a certain extent, It needs to be improved selectively, and countries need to reflect on themselves, by evaluating the health of their country's education system, and selectively making improvements from the four indicator factors. At the same time, a predictive model based on the MLP multilayer perceptron is constructed, which effectively measures the health of the country's higher education system and reflects the country's current education status and future education levels without intervention. The formulation of education policies provided direction and sounded a wake-up call for the country in education.

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