Models for Higher Education System Evaluation

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Abstract

Higher education is an important part of the national education system, and its healthy development plays an important role in supporting the country's economic and social development. This paper constructs a national higher education health assessment system from four dimensions: equity, input, quality and output. The hierarchical analysis method is combined with the entropy weighting method to determine the weights of each indicator and to assess the state of higher education in major countries around the world. On this basis, taking France as an example, principal component analysis is used to establish a national higher education problem detection model to identify the problems and main improvement directions of national higher education. It also puts forward rationalised suggestions for the healthy development of education in France.

Keywords: *Higher Education; Evaluation models; PCA; AHP;*

1. Introduction

Education is the cornerstone of social progress. Higher education, as a professional education based on secondary education, is an important part of the national education system. It is the final ground for people to enter a full social life, producing citizens with a high level of education for the country [1]. Due to the different national conditions of different countries, they have adopted different methods of developing higher education. As a result of these approaches, higher education has developed differently in each country. The United States has developed into a world-renowned higher education power, while higher education in many Asian, African and Latin American countries is still at a lower level [2]. At this point, it is important to develop an accurate model to assess the higher education system in each country to help countries understand the problems in their own higher education development. Existing studies have tended to focus on individual aspects of higher education in a country or region, and fewer studies have looked at the development of higher education in a country as a whole. The aim of this article is to develop a model for assessing the development of higher education that is applicable to most countries and to help countries identify key issues in their higher education development, with a view to ultimately creating a healthier and more sustainable higher education system.

2. Construction of the indicator system

Combining previous research, we believe that the health of a country's higher education development can be evaluated in four dimensions: equity, quality, investment and output. In this regard, we have selected a total of 12 indicators in these four dimensions [3], as illustrated in Table 1:

Table 1. Specific components of the indicator system

Tier 1 indicators	Tier 2 indicators	Tier 3 indicators
National Higher Education Health Levels	Fairness	Gross enrollment rate of higher education age population(F1)
		Gender parity index(F2)
	Investment	Government expenditure on higher education as % of GDP(I1)
		Government expenditure per higher education student(I2)
		Teacher salaries as % of total expenditures of higher education institutions(I3)

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Tier 1 indicators	Tier 2 indicators	Tier 3 indicators
	Quality	Proportion of masters and doctors in higher education(Q1)
		Number of highly cited scientists(Q2)
		Teacher-student ratio(Q3)
	Output	Graduate employment competitiveness(O1)
		Scientific research output(O2)
		Proportion of highly educated labor force(O3)
		Number of higher education institutions in the top 500 academic rankings of Shanghai Jiao Tong University(O4)

3. Model selection and construction

3.1. Data acquisition and pre-processing

For the 12 indicators in the indicator system, we have obtained relevant data for 16 countries from a number of authorities such as the World Bank, the OECD and Clarivate Analytics. For some countries, data for some indicators were missing for some years and we used the multiple imputation method in SPSS to fill in the missing values. The data was normalised before it was used. All indicators are divided into three categories: positive indicators, that is, the bigger the better. Negative indicators, that is, the smaller the better. Special indicators perform best at a specific value. Their formulae are shown below.

$$\boldsymbol{r_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}} \tag{1}$$

$$\boldsymbol{r_i = \frac{X_{max} - X_i}{X_{max} - X_{min}}} \tag{2}$$

$$\boldsymbol{r_i = 1 - \frac{|i|}{max(|i|)}} \tag{3}$$

3.2. Calculation of weights under the AHP model

In order to establish the link between the indicators and the health of the higher education system, we plan to use Analytic Hierarchy Process (AHP) to calculate the higher education health index (HEHI). We define the following expressions.

$$HEHI = x_1F + x_2I + x_3Q + x_4O \tag{4}$$

$$F = \sum_{i=1}^{n} \alpha_i F_i \tag{5}$$

Where F, I, Q, and O represent fairness index, input index, quality index, and output index respectively, and n represents the number of indicators included in the fairness index.

After that, we constructed a judgment matrix and found its characteristic roots. Then calculate the weight vector of each indicator that meets the consistency test.

3.3. Calculation of weights under the EWM model

It is well known that AHP is relatively subjective. Therefore, we decided to use a combination of the Entropy Weighting Method (EWM) to calculate the weights in order to obtain more objective results. Since we have previously normalised the data, we directly calculate the proportion of the j-th indicator in the i-th country P_i.

$$P_{ij} = \frac{V_{ij}}{\sum_{i=1}^{m} V_{ij}} \tag{6}$$

Where V_{ij} is the value of the j-th indicator in the i-th country after normalization, and m is the number of countries. We then use the resulting scale to calculate the entropy value of the j-th indicator.

$$e_i = -\frac{1}{\ln(m) \sum_{i=1}^{m} (P_{ij} \times \ln(P_{ij}))} \tag{7}$$

The weights of each indicator under the entropy weighting method can be calculated by the following formula.

$$W_{Ei} = \frac{1 - e_i}{n - \sum_{i=1}^{n} e_i} \tag{8}$$

After the weighting calculation using the AHP model and the EWM model, we obtained the final weighting results W_i by performing a weighted average using the following expressions.

$$W_i = y_1 W_{Ai} + y_2 W_{Ei} \tag{9}$$

Where W_{Ai} represents the weight of the i-th indicator calculated by AHP, and W_{Ei} represents the weight of the i-th indicator calculated by EWM. We estimate the values of y_1 and y_2 to be 0.3 and 0.7, respectively. Finally, the weights of the indicators are shown in Table 2.

Table 2. Results of the combination of AHP and EWM

Dimension	Indicator	Coefficient
Fairness	Gross enrollment rate of higher education age population(F1)	0.05365

Dimension	Indicator	Coefficient
	Gender parity index(F2)	0.04635
Investment	Government expenditure on higher education as % of GDP(I1)	0.05964
	Government expenditure per higher education student(I2)	0.09068
	Teacher salaries as % of total expenditures of higher education institutions(I3)	0.04968
Quality	Proportion of masters and doctors in higher education(Q1)	0.09519
	Number of highly cited scientists(Q2)	0.10036
	Teacher-student ratio(Q3)	0.03618
Output	Graduate employment competitiveness(O1)	0.14704
	Scientific research output(O2)	0.1147
	Proportion of highly educated labor force(O3)	0.0444
	Number of higher education institutions in the top 500 academic rankings of SJTU(O4)	0.0938

3.4. The application of models in national higher education assessment

Having completed the modelling above, we apply it to data from 15 real countries. We compare the calculated Higher Education Health Index (HEHI) indices and analyse the results for each country.

In order to facilitate the classification of the country's level of health in higher education development, we have set thresholds to classify the country's higher education into healthy, sub-healthy and unhealthy levels, the criteria for which are shown below.

$$Status = \begin{cases} \text{Healthy} & HEHI \geq 30 \\ \text{Sub}-\text{healthy} & 30 > HEHI \geq 15 \\ \text{Unhealthy} & 15 > HEHI \geq 0 \end{cases} \quad (10)$$

The figure 1 and table 3 show the result.

Table 3. The health of higher education in various countries

Status	Country	
Healthy	Canada	United Kingdom
Sub-healthy	Australia France Japan Switzerland	China Germany Singapore
Unhealthy	Brazil Mexico South Africa	India Russia Turkey

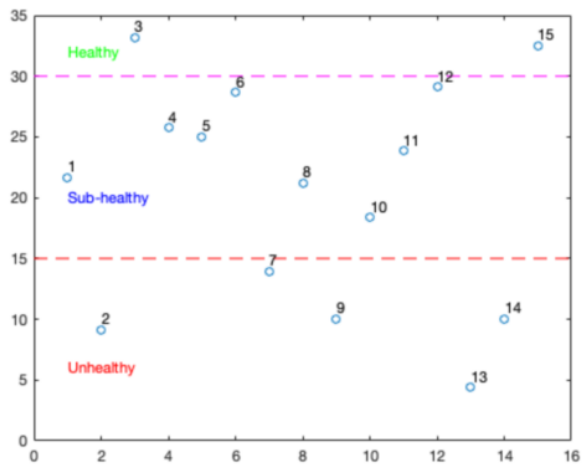

Figure 1. The health of higher education in 15 countries

From the results we can gather that developed countries are generally ahead of the curve in terms of higher education development. The health of higher education in less developed countries, tends to lag behind, and this is likely to be the reason why their countries as a whole are lagging behind.

4. Improvement of national higher education at a given level

After obtaining the level of health of the country's higher education, it is more important to analyse the problems based on the results and give solutions to promote the development of the country's higher education. We have chosen France as an example for a specific analysis.

4.1. Directions for improvement based on the current situation in France

It is clear from the above that the current level of higher education in France is in a sub-healthy state. Combining the results of the model constructed above, we obtained scores for France on 12 indicators and compared them with the average of all 15 countries. The results are shown in Figure 2.

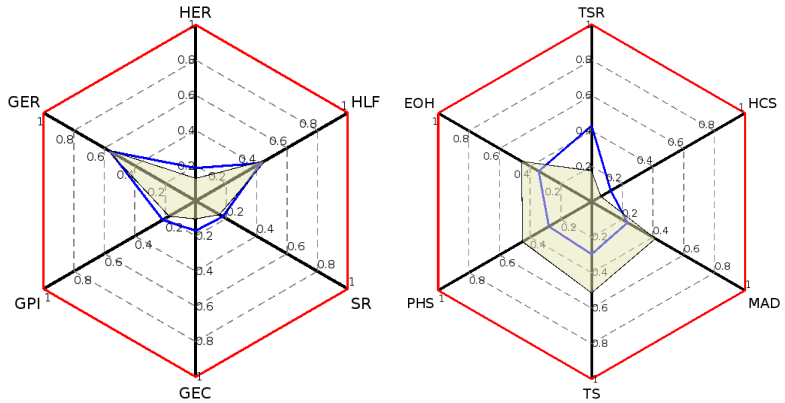

Figure 2. Various indicators of French HEHI

From this figure, we find that although France is already a higher education sub-health country, there are still 5 indicators with obvious defects in the 12 indicators. They are Gender parity index (GPI), Scientific research output (SR), Number of higher education institutions in the top 500 academic rankings of SJTU (HER), Teacher-student ratio (TSR), Number of highly cited scientists (HCS).

There are certain gaps between these indicators, both in relation to other national indicators and to international averages. These indicators for France are therefore a current direction for improvement.

4.2. Directions for improvement based on the impact of indicators

Next, we consider the influence of various indicators on the health of the French higher education system. We used a variant of Principal Component Analysis (PCA) to analyse these indicators.

Here we use the eigenvalue decomposition algorithm of the correlation matrix to implement PCA. Since our data has been past-centred, we directly build the correlation matrix for each indicator. Here the data for each indicator is represented by the matrix X. The formula for each correlation matrix R is as follows.

$$R = [r_{ij}]_{m\times m} = \frac{1}{n-1} XX^T \tag{11}$$

Based on the matrix results, we removed four indicators with low correlation. Next, we carried out a principal component analysis of the eight indicators for the selected countries. These eight indicators are: Gross enrollment rate of higher education age population (GER), Government expenditure on higher education as % of GDP(EOH), Teacher salaries as % of total expenditures of higher education institutions (TS), Number of highly cited scientists, Graduate employment competitiveness (GEC), Scientific research output, Proportion of highly educated labor force (HLF), Number of higher education institutions in the top 500 academic rankings of SJTU. Next, we calculated its eigenvalues and eigenvectors and obtained its principal components.

After that, we extracted the common factors (principal components). According to Figure 3, we extracted the first three common factors, which have a cumulative variance contribution of 92.499% (>85%). This indicates that these three factors capture most of the information on the variables and are a valid indicator of the health of higher education [4].

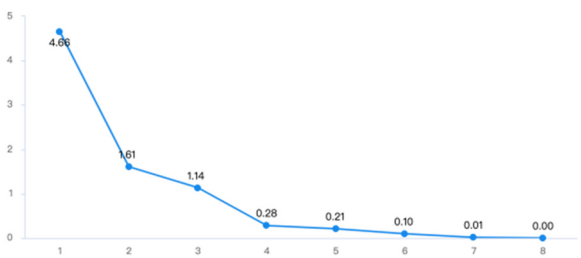

Figure 3. Gravel map

We then used the loading factor table to show the correspondence between the three principal components and each indicator. The loading factor table is shown below. The closer the absolute value of the loading

factors of the variables and principal components is to 1, the closer the relationship between the variables and the principal components is. The closer the relationship between the variables and the principal components.

Table 4. Loading factor table

Indicator	Load factor			Common degree
	principal component 1	principal component 2	principal component 3	
GER	0.562	-0.677	0.343	0.892
EOH	0.446	0.176	0.837	0.929
TS	-0.305	0.794	0.422	0.902
HCS	0.943	0.246	-0.160	0.975
GEC	0.926	0.189	-0.157	0.919
SR	0.943	0.278	-0.123	0.982
HLF	0.735	-0.498	0.201	0.828
HER	0.934	0.258	-0.184	0.973

Based on the results of the linear combination coefficients and weights, we can calculate the comprehensive score coefficients for the eight key indicators. The results are shown in Table 5.

Table 5. Comprehensive score coefficient

Indicator	Comprehensive score coefficient
GER	0.0974
EOH	0.2806
TS	0.1086
HCS	0.2940
GEC	0.2799
SR	0.3050
HLF	0.1580
HER	0.2901

Based on principal components analysis and the national context of French higher education. We found that France is most eager and effective to improve on the following indicators: Gender Parity Index, Scientific Research Output, Number of Higher Education Institutions in the Top 500 Academic Ranking of SJTU, Teacher-Student Ratio, Government Spending on Higher Education as a Percentage of GDP, and number of highly cited scientists.

4.3. Policy recommendations

In order to complete the transition from the current state of French higher education to a healthy state, we will propose the following policies in light of the analysis above.

To promote gender equality in higher education, the government and parliament can issue relevant bills and guidelines. We will require colleges and universities to reserve a certain number of places for women at the time of admission. In addition, the relevant government agencies can monitor the implementation of the law in higher education institutions and take punitive measures such as withdrawal of funding for higher education institutions that do not implement it effectively [5].

Government investment in higher education needs to be steadily increased. The State and major regions and provinces establish and improve the system for securing funding for higher education, and actively guide society to increase its investment in higher education. Strengthen the management of higher education funding and improve the efficiency of its use.

The teacher-student ratio is an important indicator of the quality of higher education, and there is a large gap in the strength of teachers in French higher education. We believe that France should introduce relevant policies to provide more funding for schools that set up teacher training programs to train more teachers. At the same time, it should actively bring in high-level education talents from abroad and provide the necessary guarantees such as funding, visas and long-term residence permits for the talents to expand the sources of higher education teachers.

A healthy higher education system must be supported by high-level talent. To this end, France could increase its national research funding to provide more adequate research support for high-level talent. We will improve the national honours and awards mechanism and award national titles to high-level outstanding talents to stimulate their motivation.

5. Conclusion

In this paper, we develop a model to assess the health of national higher education systems, considering four dimensions: equity, input, quality and output. We then apply the model to data from 15 countries and conclude that the development of higher education in developed countries is generally better than in developing countries. The model was further extended to detect national higher education problems, and using France as an example, we analysed its current problems and key directions for future improvement, and gave policy recommendations.

From a theoretical point of view, this paper introduces traditional methods from computer disciplines such as

AHP, EWM and PCA into relevant pedagogical research, which to a certain extent enriches and contributes to the development of higher education-related research. On a practical level, this paper's research on the health of national higher education systems helps national governments to have a general grasp of the development of higher education in their countries, identify its current core problems and adopt corresponding policy measures, so as to promote the healthy development of higher education in their countries. In the future, we will further refine the model and refine the indicators to make it more universal and better guide the development of higher education in each country.

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