Comprehensive Analysis of the Health and Sustainability of National Higher Education

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Abstract: Education is the foundation and driving force of a country's development. Higher education is the most essential and complex part of the entire national education system. Over the past decades, the expansion of higher education has become a mainstream of the global higher education development. It has had a far-reaching influence on many aspects of a country like society, economy, politics, and culture.In this paper, we aim to construct a health evaluation model and a sustainability evaluation model to assess higher education development in all countries around the world. We hope this evaluation system can help governments make targeted development plans according to the assessment results.

1. Background of the problem

Education is the foundation and driving force of a country's development. Higher education is the most essential and complex part of the entire national education system. Since the middle of the 20th century, the new science and technology revolution has brought mankind into a new era of knowledge economy, with rapid development of economic globalization and knowledge economy [1]. In the international context of the great development of the world economy and society, the world higher education is undergoing profound changes, and the higher education in each developed country also shows some common development trends. The size of a country's higher education student population not only determines the future level of its human resources, but also affects the entire world's human resource pool and the direction of the talent market. There are 60 countries in the world where higher education is less developed, and the average gross enrollment rate in higher education in these countries is about 7.25%, among which, more than 70% of the countries have a global tertiary enrolment ratio (GTER) of less than 10%. The evaluation system of the education system has become particularly important in the process of promoting the universalization of higher education. This evaluation system should be able to evaluate the level of the higher education system as well as its strengths and weaknesses and provide targeted improvement methods to address the shortcomings of the education system.

2. Relative work

Education at A Glance: OECD Indicators published by the Organization for Economic Cooperation and Development (OECD) is a representative international report [*]. This report focuses on the basic indicators include the ratio of education expenditure to GDP, public expenditure on education, and the number of full-time teachers.

The World Education Report released by UNESCO is a more authoritative and common education indicator system, which includes the ratio of education expenditure to GDP, student-teacher ratio, gross enrollment rate, literacy rate and other indicators [2].

Competitiveness Report, which uses relevant indicators for competitiveness evaluation, in which the indicator layer of higher education and training contains indicators such as secondary education enrollment rate, higher education enrollment rate, and quality of education system, reflecting the quality and scale of higher education [3].

3. Indicators of national higher education

3.1 Selection of the indicators

There are many indicators in the national higher education system to measure itself. Among these indicators, we select eleven representative indicators as secondary indicators:

Performance of national higher education:

The performance of the national higher education are the academic result, scientific results, and other achievements. The main indicators are number of papers, degree value (QS ranking), number of Nobel Prize winners, and education index.

Input of national higher education:

The input of national higher education includes the input of the government, the number scale of higher education institution, and the payment of the students. These factors directly decide the resources of a higher education institution and directly influence the development of national higher education.

Output of national higher education:

The output of education focuses on the result of investment and input. Indicators like student number, student prospects (employment rate), opportunity for education (enrollment rate) and fairness (gender ratio) will determine the future of the national higher education.

Table 1: Indicators in our problem

Indicator classification	Secondary indicators	Representation
The performance of national higher education	Number of papers	X_1
	Degree value (QS ranking)	X_2
	No. of Nobel Prize Winners	X_3
	Education Index	X_4
The input of national higher education	National education investment proportion	X_5
	Number of school boards	X_6
	Average tuition	X_7
The output of national higher education	Student prospects (employment rate)	X_8
	Number of students	X_9
	Opportunity for education (enrollment rate)	X_{10}
	Fairness (male to female ratio)	X_{11}

We take the data form specific country and specific year as an example. According to the analysis above, we mainly select eleven representative indicators as secondary indicators and divide them into three categories.

When conducting multivariate statistical analysis, different indicators are measured by different magnitudes. That may lead to huge differences between several indicators. Under this kind of situation, variables are not integrated [4]. Some indicators with big order of magnitude will always have a significant influence on the results. So, the calculation results may not be realistic because the measurement of the indicator is not uniform.

We perform the normalization process to modify the indicators between zero to one. Later in neural network algorithm, this procedure can improve model and increase convergence speed.

We conduct the normalization process:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

X_{norm} represent the data after normalization.

X represent the original data.

X_{max} represents the maximum data in original dataset

X_{min} represents the minimum data in original dataset.

After the normalization, indicators with different magnitudes will be normalized to the range of $[\mathbf{0}, \mathbf{1}]$.

3.2 Dimensionality reduction (Using Factor Analysis Method)

Factor analysis mainly considers the interrelationships among indicators and converts multiple indicators into a few uncorrelated variables using dimensionality reduction methods. The group of variables after conversion is called principal components [5]. The conversion can show a more objective weighting. Thus, it is a statistical method that further makes the study simple. In this paper, we apply factor analysis method in analyzing correlation between eleven indicators to extract principal factors. We conduct factor analysis algorithm directly on the data of 6 countries for 5 years.

3.3 Step of factor analysis method

First, we perform KMO (Kaiser-Meyer-Olkin) and Bartlett's tests to determine whether principal component analysis could be performed.

The table below shows the results of KMO test and Bartlett's test.

Table 2: Result of KMO test and Bartlett's test

KMO test and Bartlett's test		
KMO		0.614
Bartlett's test	Approximate cardinality	434.998
	Degrees of freedom	55.000
	Significance (P)	<0.0001

The KMO test is passed (KMO>0.6). It indicates that there is a correlation between the question variables, which meets the requirements of factor analysis.

The Bartlett test is passed. P stands for the significance of the Bartlett's test. P < 0.01, which indicates that the variables are correlated and suitable for factor analysis.

Then we determine the number of principal components by analyzing the variance

interpretation.

According to the variance interpretation table, the cumulative variance contribution rate of the top 3 factors was 90.337%. Feature root is less than one when it comes to factor 4. It indicates that these 3 factors reflect the information of most variables and can effectively reflect the level of higher education development level.

By analyzing the heat map, we analyze the importance of the hidden variables in each principal component.
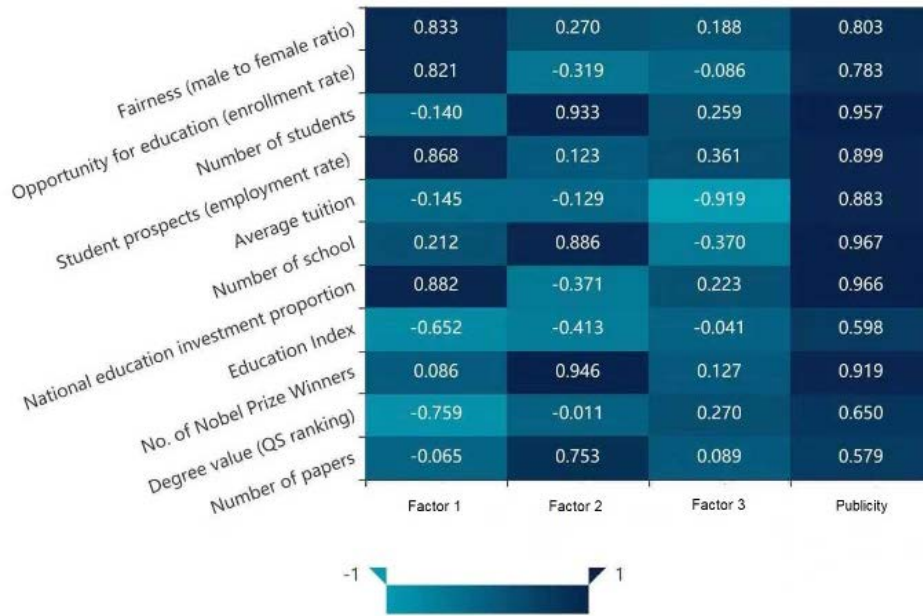

Figure 1: Heat map of Factor Analysis

We can get that the first common factor F1 has a large component in X_1, X_2, X_4, X_7. Second common factor F_2 has a large component in X_3, X_6, X_9, X_{11}. Third common factor F_3 has a large component in X_5, X_8, X_{10}.

The result is different from the three categories that we divide in previous. So, we reconsider the categories and redivide the categories. The we get three primary indicators. We take F1 as the indicator of performance of the higher education, F2 as the input of the higher education, and F3 as the output of the higher education.

Next, we get the principal component formula by analyzing the component matrix.

Based on the matrix of component coefficients, the equation expressions for the five common factors.

$$F_i = \alpha_{i1}X_1 + \alpha_{i2}X_2 + \cdots + \alpha_{in}X_n = \sum_{j=1}^{n} \alpha_{ij}X_n$$

$F_i(i = 1,2,\ldots,n)$ is score of each component.
$\alpha_i(i = 1,2,\cdots n)$ is the contribution of each component.

The composite scores of the principal components are obtained by multiplying the scores of each component with the contribution of the rotated principal components separately. The specific expression is

$$\text{Performance of the education} = 0.092*X_1+0.438*X_2+0.374*X_4 - 0.065X_7$$
$$\text{Input of the education} = 0.469*X_3 - 0.322*X_6+0.434*X_9 + 0.017*X_{11}$$
$$\text{Output of the education} = 0.092*F_5+0.438*F_8+0.374*F_{10}$$

Then, we have reduced the twelve-dimensional indicators into three dimensions. At last, we use the three primary indicators as the input of the neural network and train our evaluation model.

3.4 Conclusion

This part is the preprocess of the data. We collect eleven representative indicators as secondary indicators. Later, we divide the eleven secondary indicators in to three categories according to common sense. We define these three categories as the performance, input, and output of the national higher education. Then we want use Factor Analysis Method to extract main indicators and we find it can rearrange the categories. So, we use new categories as three primary indicators. Later we will take three primary indicators as the input of the neural network and train our evaluation model.

4. Conclusion

In this paper, we mainly establishment a health evaluation model and a sustainability evaluation model to assess the higher education in all countries around the world. There are many indicators that describe the education system in every aspect. We first select eleven most representative indicators to describe national education development and preprocess of the data. Then we build our evaluation model based on the BP neural network. We collect data from six countries to train our model. After training, we build a five-level standard evaluation system of the national higher education. So, we can evaluate every country in the world and analyze the strength and shortage of the higher education system. According to the analysis, we can help countries to design improvement plans and schedule. We also use a sustainability evaluation model to predict and indicate the effective of our strategy. That is the practical value of our evaluation system.

In addition, we also conduct an improvement of our model to make it have a high speed and better precision. This pattern can also be implemented into other fields, such as economy, agriculture, and culture. We should modify the indicators and model base on different field, and we believe it will help us make better evaluation and decision in improvement strategy.

References

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