

Education Rating! The Health of Higher Ed System

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Abstract: With the progress of the world as a whole, we are more and more aware of the importance of a healthy and sustainable higher education system for a country. Every country's higher education system has its advantages and disadvantages. Under the background of the epidemic situation, we should pay more attention to which factors affect the higher education system, and what is the degree of influence, so as to find the breakthrough point and realize the health, sustainability and reform of the higher education system. Based on the data collection, integration, calculation and modeling of 9 indicators in 26 countries, this paper finds out the methods to evaluate the advantages and disadvantages of a country's higher education and the main influencing factors, so as to help countries with room for progress to formulate development plans and realize institutional change.

1. Introduction

Higher education is the cornerstone of a country's future. The higher education system is like the heart of the human body. The vigorous beating of the "heart" continuously provides fresh blood for a country. A healthy and sustainable higher education system will train outstanding talents from all walks of life for its country, bring technological innovation and economic development, and make the country more competitive on the international stage.

It can be said that measuring and evaluating the health of the higher education system at the national level has very profound practical significance. There are many indicators to measure a country's higher education system, such as government investment, accessibility of education, number of scientific researchers, top universities and so on. There are some very critical indicators hidden in these complex factors, which need to be discovered urgently.

The COVID-19 sweeps the world, bringing global economic stagnation and the loss of countless lives, but it is also a critical chance, especially for a country's higher education system: whether to maintain the original state or reform. We will establish a series of models to create a higher education system index (HESI) that is applicable to most countries, and provide some positive and feasible reference opinions for the reform of higher education systems in various countries.

2. Assessment of the Health of the Higher Education System

2.1 Our Primary Indicator System

In order to better evaluate if a country's higher education system is healthy and sustainable, we have selected 9 indicators. According to the analysis framework of background, invest and output, we divided these **9 indicators** into **3 levels** to evaluate the **HESI** of each country.

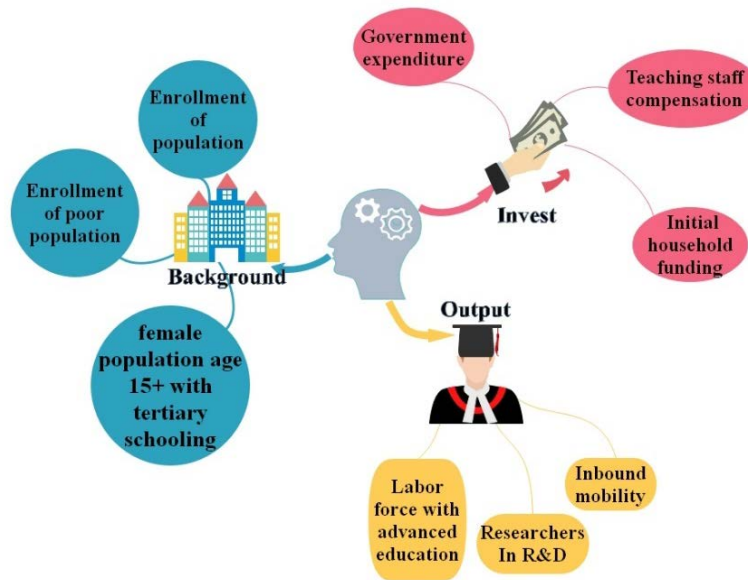


Figure 1. Our primary indicator system

➤ Background

(1) Enrollment of population X_1 (% of gross attendance for tertiary education, both sexes)

The number of enrollments in higher education is an important indicator to measure the degree of higher education. We choose gross enrollment ratio for tertiary education, which is positively related to the sustainable development of the higher education system.

(2) Enrollment of poor population X_2 (% of gross attendance for tertiary education, poorest quintile, both sexes)

When the poorest quintile of the population also has the opportunity to study in higher education institutions, the country's higher education system will be more accessible and healthier. Therefore, we introduce the gross attendance ratio for tertiary education (poorest quintile) to reflect the total enrollment rate of the poor.

(3) Female population age 15+ with tertiary schooling X_3 (% of total, Incomplete and Completed Tertiary)

Women's right to education always appears as a synonym for social justice, which can also fully reflect the health of a higher education system. Therefore, we choose percentage of female population age 15+ with tertiary schooling to measure women's right to education.

➤ Invest

(1) Government expenditure on tertiary education X_4 (% of GDP)

The government is an indispensable role in the higher education system, and the maintenance of

the higher education system often requires government financial support. We introduce higher education expenditure as a percentage of GDP to represent the government's emphasis on higher education, which determines whether the country's higher education has the motivation for sustainable development.

(2) Teaching staff compensation X_5 (% of total expenditure in tertiary public institutions)

Teaching staff are one of the important components in the higher education system. Excellent teaching staff can cultivate more outstanding tertiary students. Usually, high compensation can attract more excellent teaching staff. Therefore, we choose teaching staff compensation as a percentage of total expenditure to measure a country's investment in higher education.

(3) Initial household funding X_6 (dollars per tertiary student, constant PPP)

Students are another important component of the higher education system. In order to enable more talented students to have further study opportunities, funding for college students will be particularly important. Therefore, we choose initial household funding per tertiary student as an indicator to measure the health of the higher education system.

➤ **Outcome**

(1) Labor force with advanced education X_7 (% of total)

The health of the higher education system determines whether the population with higher education can have more job opportunities. Therefore, we choose the labor force with advanced education of total as the index to evaluate the health of the higher education system.

(2) Researchers In R&D X_8 (per million people)

When evaluating the level of higher education, scientific research results often become important indicators. Therefore, we have selected the number of researchers in R&D per million people as the index to measure scientific research results.

(3) Inbound mobility X_9 (% of total, both sexes)

The number of international students is often directly proportional to the output level of the higher education system. Only a high-quality higher education system can attract more international students. Therefore, we choose the inbound mobility rate as one of our indicators.

2.2 Cluster Analysis

We clustered 26 randomly selected countries using 9 indicators related to the health of higher education. Through clustering, we can have a macro understanding of the development of higher education systems in these 26 countries. The clustering result can support us to explore the correlation and difference between different categories of countries.

First, we choose to use the K-means clustering method to classify countries. Because the data dimensions of the selected indicators are inconsistent, we standardize them $z_i = \frac{x_i - \bar{x}}{\delta_x}$. The final

clustering results are shown in the following table:

Table 1 K-means cluster analysis results

No.	Country Name	Cluster	Distance	No.	Country Name	Cluster	Distance
1	Japan	1	1.516	14	India	3	2.177
2	United States	1	1.516	15	Iran	3	1.26
3	Canada	2	1.576	16	Italy	3	1.25
4	Switzerland	2	1.446	17	Mexico	3	1.59
5	Germany	2	1.798	18	Malaysia	3	2.041
6	Finland	2	2.221	19	Peru	3	2.113
7	United Kingdom	2	2.479	20	Thailand	3	2.168
8	Ireland	2	1.797	21	Honduras	4	1.976
9	Argentina	3	1.907	22	Indonesia	4	1.786
10	Armenia	3	2.4	23	Mongolia	4	2.083
11	Bulgaria	3	1.598	24	Nepal	4	3.402
12	Brazil	3	2.738	25	Vietnam	4	1.826
13	Colombia	3	1.438	26	South Africa	4	1.472

We use the preset category $K = 4$, and after 20 iterations of the data, we divide the countries into four categories:

Cluster 1. Countries with excellent higher education systems: the United States and Japan.

Cluster 2. Countries with healthy higher education systems: Canada and Switzerland are the representatives.

Cluster 3. Countries with Sub-healthy education systems: represented by Argentina, Brazil, and Mexico.

Cluster 4. Countries with poor higher education systems: Honduras, Indonesia and other countries.

It can be seen that the clustering results are in line with our common sense understanding. The K-means clustering can process a large amount of data concisely and efficiently, but it also has obvious shortcomings, for example, it is subjective in the selection of K value.

In order to deal with this weakness, we chose to use the Elbow Method to estimate the optimal number of clusters. To measure the degree of total distortion, the formula can be expressed as:

$$J = \sum_{k=1}^K \sum_{i \in C_k} |x_i - u_k|^2$$

K is the number of clusters, n is the number of samples (in our case $n=26$), C_k represents the k -th class, and the center is u_k . The abscissa is the number of clusters K , and the ordinate is the Clustering coefficient.

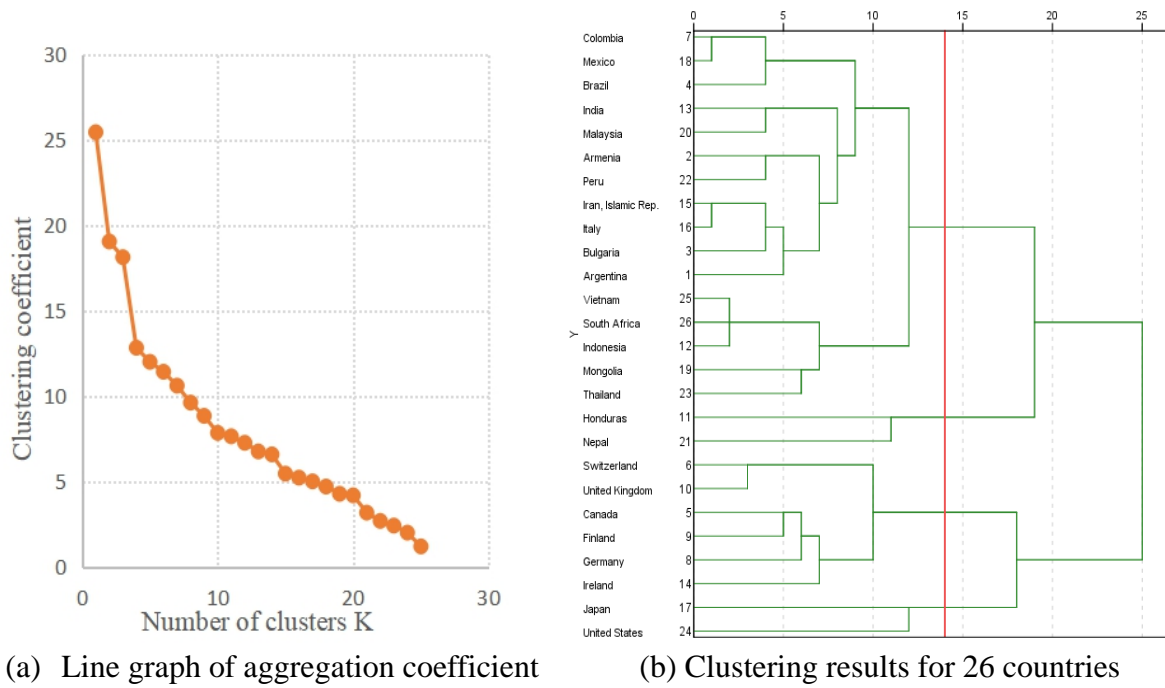


Figure 2. Hierarchical cluster analysis

According to the Clustering Coefficient line chart, when the number of categories is 4, the downward trend of discount from a steep to flattening. Therefore, it can be considered that the selection of $K = 4$ is reasonable.

We apply another clustering method: Systematic Clustering, which clusters 26 countries again and divides them into 4 groups. From the Figure 2 (b), we can see that the results obtained by the Systematic Clustering are consistent with the results obtained by K-means clustering.

3. Sensitivity Analysis

Through the above nine indicators, we can see the impact of each indicator on the national higher education system through the data. These indicators are classified into three categories according to the previous section. They are Background (indicated by letter A), Invest (indicated by letter B) and Outcome (indicated by letter C). We use sensitivity analysis method to analyze the sensitivity of entropy weight model, and get the sensitivity of these three categories.

The expression of sensitivity analysis is

$$\frac{\partial H}{\partial A} = \frac{\partial H(A, B, C)}{\partial A}$$

$$\frac{\partial H}{\partial B} = \frac{\partial H(A, B, C)}{\partial B}$$

$$\frac{\partial H}{\partial C} = \frac{\partial H(A, B, C)}{\partial C}$$

Sensitivity of three first level indexes:

Index	A	B	C
Sensitivity	0.38468	0.35822	0.25709

It can be seen from the above table that Background has the greatest impact on the higher education system, followed by the Invest, so our indicators are representative.

4. Strengths and Weaknesses

4.1 Strengths

- **Strong scientific data:** the data used in this paper are real data, with many sample countries and indicators, and the conclusion is more persuasive.

- **Abundant use of models:** This paper mainly involves five models, and cluster analysis reasonably classifies the sample countries into four categories for further analysis. Entropy weight method use four representative countries to build the model and get the weights of nine indicators, which is accurate and not cumbersome. Principal component analysis has successfully achieved dimension reduction, which makes our data analysis more targeted. The grey prediction model selects Mexico as the country to predict the scores of higher education system in the next few decades, and then puts forward a reasonable development plan and arranges the implementation schedule.

- **Strong adaptability:** the model can evaluate the higher education system of any country. Macroscopically, we have a general grasp of the quality of higher education in different countries around the world

- **High practical value:** judging from the grey prediction model of Mexico, these models can be well applied to the real world.

- **By using the scoring system,** we can compare the scores of different countries, so as to get the gap between different countries. We can model and analyze the countries that need to be improved, and put forward reasonable suggestions for them.

4.2 Weaknesses

- **There may be sidedness,** and the 9 selected indicators may not be enough to reflect all the details

- **No consideration of extreme situations:** the 26 selected countries are basically countries with relatively conventional higher education system, while we do not consider countries with extremely poor and backward education. This is a problem.

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