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A healthy and sustainable higher education system based on AHP

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Abstract: Having a healthy and sustainable higher education system is of paramount importance. This paper first selects and analyzes several indicators and establishes an evaluation model to score four countries. First, we select four representative countries. Then, we select two indicators that have greater influence on the higher education system in the aspect of economy and output, while using PCA to classify the six indicators in the policy into two principal components after standardized processing. Then we establish the AHP evaluation model, after determining the weights of different indicators, the carried-out consistency test showed that CR was all less than 0.1, verifying the feasibility of the model.

1. Introduction

Higher education is an important support for social development, an important part of a country's education of citizens, and the key to improve the quality of education in all countries of the world. We can see that each country not only provides quality higher education to its own students, but also attracts international students from all over the world to study; and different countries have their own unique education system and higher education system. Different higher education systems cannot be simply compared to be able to judge the advantages and disadvantages, therefore, the quality of higher education evaluation is particularly important.

2. Evaluation Model

In order to evaluate the health status of each country's higher education system, and to make the selected countries representative at the same time, this paper selects four countries which are the United States, Japan, China and Vietnam for detailed analysis. We can find that the selection includes the developed countries and developing countries and also covers the well-educated higher education system countries and the countries which lack the well higher education regime. Therefore, this paper chooses these four countries as the research objects. They not only reflect the higher education situation in most countries in the world today to some extent, but also verify that our model is

convinced enough to evaluate the health status of any country's higher education system.

This paper boils down many indicators of higher education to the evaluation criteria of the three dimensions of economy, policy and output, and finally determines the following indicators by drawing on the research results of the evaluation of higher education.

2.1 Analysis of Evaluation Index

2.1.1 Economy

Economic indicators that we mainly select are GDP per capita and the contribution rate of the three major industries to GDP. We use these two factors to carry out the main analysis.

The first one is GDP per capita. GDP per capita is the gross domestic product (GDP) divided by the gross domestic product (GDP) of a country or region for a period of time, which is the final result of the productive activities of all permanent units in a country (or region) over a period of time. As an indicator values the state of economic development in the subject of development economics, this indicator is one of the most important macroeconomic indicators. It is an effective tool for grasping the macroeconomic health of a country or region. The higher the GDP per capita, the richer the people's lives. A comparison of GDP per capita with gross enrolment in higher education in the four countries in the chart below shows that per capita GDP has remained the highest in the United States over the selected period of time, and that China's GDP per capita has been at a high rate in recent years as a result, gross enrolment in higher education is growing faster than in Viet Nam, wherever we find that higher education remains low gross enrolment and below the world average because GDP per capita has not changed much. The study of GDP per capita shows that there is some correlation between the country's macroeconomic situation and the level of higher education, and the economic gap is to some extent can reflect the disparity in the level of higher education.

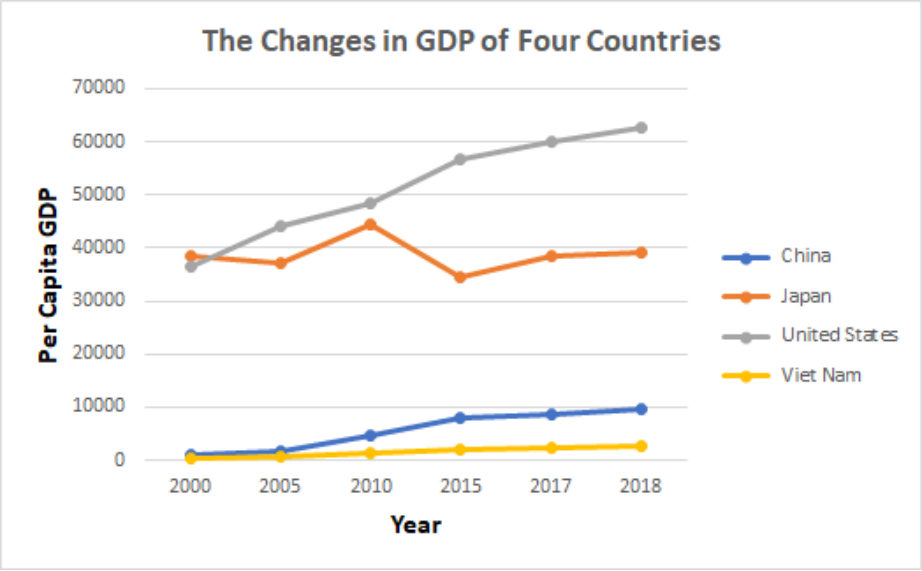

Figure 1. The Changes in GDP

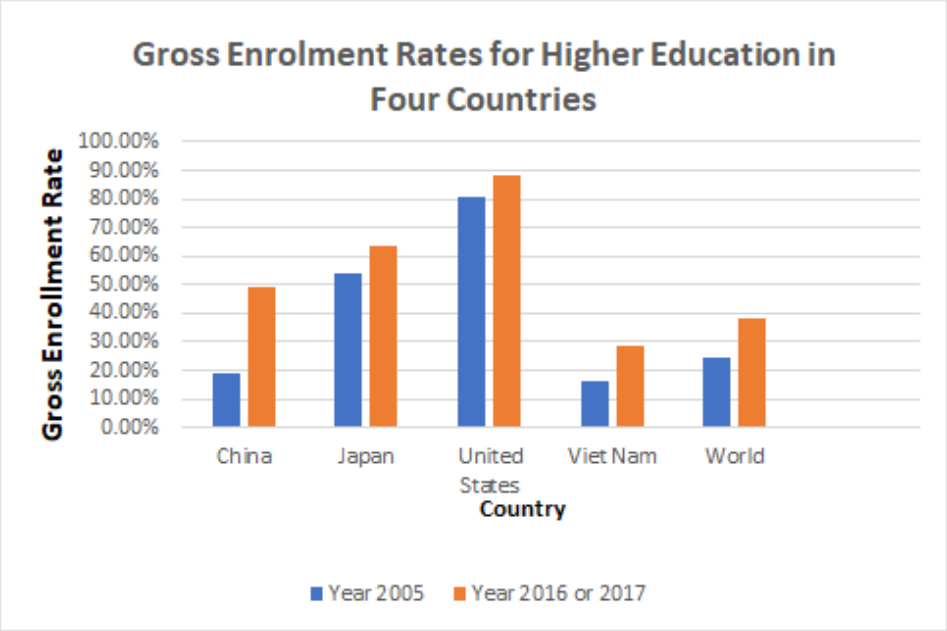

Figure 2. Gross Enrolment Rates for Higher Education

The second aspect is the contribution rate of the three major industries to GDP. The role of the three major industries in economic development cannot be ignored. Countries around the world divide all kinds of industries into three categories. The first industry refers to one that provides the means of production; the secondary industry refers to the processing industry which is related to the use of basic means of production for processing and sale. The tertiary industry is also known as the service industry. The classification of the three major industries by each country has a little bit of difference but in the same in most cases

From the chartsabove, we can find that from 2017 to 2020, the three major industries of China have been growing steadily and rapidly. Japan's secondary industry declined significantly but the tertiary industry increased sharply from negative proportion to exceed 60 percent, Vietnam's secondary industry growth is also significant and the United States' three major industries are steadily rising. By comparing the changes with indicators such as school enrolment rates in each country during the period, we can figure out the relevance.

2.1.2 Policy

(1) Indicator

At the political dimension, we first selected four indicators: public education input, industrial structure, gross enrollment rate and research input.

In terms of public education inputs, we can see non-significant change in numerical values in all four countries between 2010 and 2016. China and Japan are slightly below the world average for public education, but China has also increased during this period. The U.S. and Vietnam are spending more than average level, and Vietnam's share of investment has continued to grow and over the U.S. in 2016. We can see the great attention that Vietnam has put to educational input aspect.

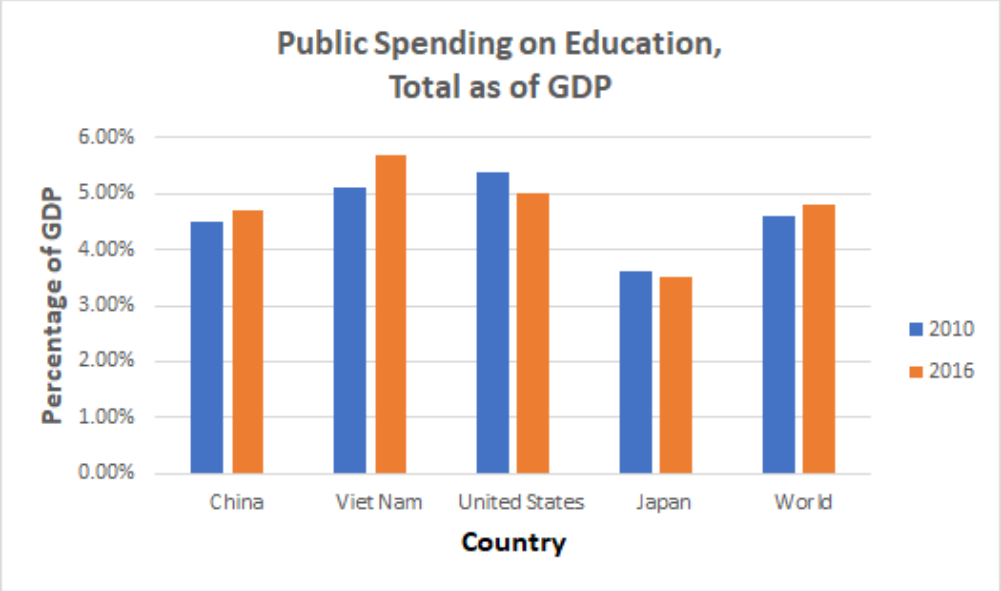

Figure 3. Public Spending on Education

In terms of research inputs, all four countries grew slightly or were essentially flat between 2010 and 2016. The U.S. and Japan have grown far more in research than the world, but Vietnam's share of research spending is only a few-tenths of that of other countries and well below world levels. It can be seen here that Vietnam lags far behind in research.

In terms of industrial structure, a reasonable industrial structure can promote the high-quality development of the economy, thereby stimulating GDP growth and promoting the development of higher education. Among the three major industries, the prosperity of the tertiary industry is an important feature of the modern economy. The higher the level of tertiary industry development, the smaller the proportion of the primary industry, which indicates the higher the level of social productivity and the economic benefits of the whole country. From the chart below, we can see that the tertiary industry in the United States and Japan accounts for much higher proportion of GDP than the first and second industries; China's industrial composition is mainly the second and third industries higher than the proportion of the first industry in GDP; while the distribution of Vietnam is more balanced among the three industrial structures. Therefore, we can evaluate the impact of industrial structure on the quality of higher education system through three different industrial structures.

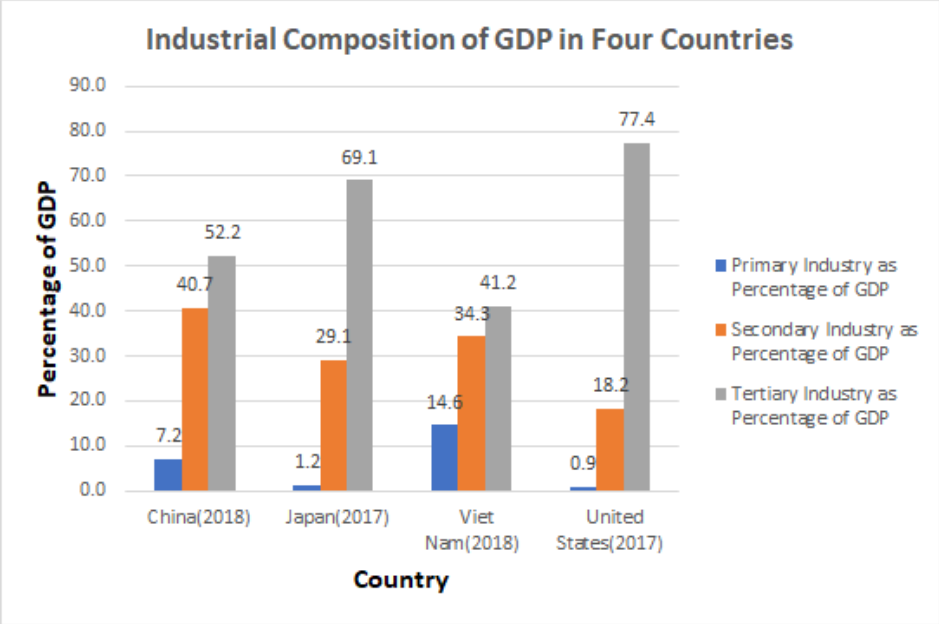

Figure 4. Industrial Composition of GDP

In terms of enrolment rates, in fact, the key to increasing student enrolment in higher education is to improve the quality of higher education; As can be seen from Figure 2 above, the U.S. higher education enrollment rate has been maintained at a high level, ranking among the highest in the world, far beyond the world; Japan also has a higher-than-average enrolment rate, while China's development in recent years has led to rapid growth in enrolment rates, from below-average to above-average, but Vietnam has always been keeping enrolment rates low. These figures are also consistent with the high quality of higher education in the United States and the poor quality of education in Vietnam

(2) Principal Component Analysis

In the policy dimension, we started with six indicators of public spending on education, industrial structure, gross enrolment rate, research expenditure, and unemployment rate and education expenditure. Considering that the indicators may be related to each other, coordinates are transformed of the indicator, so that it rotates orthogonally to a new axis that is unrelated to each other, removing redundant data.

First of all, in order to eliminate the effect of different differences in the variable dimension, we standardize the variables. There are four geographic samples, each with six variables, forming a 4x6-order geographic data array:

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & \cdots & x_{16} \\ \vdots & \ddots & \vdots \\ x_{41} & \cdots & x_{46} \end{bmatrix} = (X_1, X_2, X_3, X_4, X_5, X_6)$$

This time should be 6-dimensional space, and then we carry out dimensional reduction processing, with fewer comprehensive variables instead of the original more variables, so that these fewer comprehensive variables can reflect as much as possible the information reflected by the original more variables. After Kaiser-Meyer-Olkin (KMO) test, we conclude that the partial correlation

coefficient between the variables is greater than 0.5, which means the principal component analysis can be performed.

We use the linear transformation method to make the new comprehensive variable a linear combination of the original variables:

$$\begin{cases} F_1 = a_{11}x_1 + a_{21}x_2 + \cdots + a_{61}x_6 \\ F_2 = a_{12}x_1 + a_{22}x_2 + \cdots + a_{62}x_6 \\ \vdots \\ F_6 = a_{16}x_1 + a_{26}x_2 + \cdots + a_{66}x_6 \end{cases}$$

Equaling to $F_i = a_{1i}x_1 + a_{2i}x_2 + \cdots + a_{6i}x_6$, $i = 1,2,3,4,5,6.$

We call $\frac{Var(F_1)}{\sum_{i=1}^{6} Var(F_i)}$ as the first principal component contribution rate, the greater the contribution rate of the first principal component, the stronger its ability to combine the information of $X_1, X_2, X_3, X_4, X_5, X_6$. We call $\frac{\sum_{i=1}^{k} Var(F_i)}{\sum_{i=1}^{6} Var(F_i)}$ as cumulative contribution rate of the first k principal components, if the cumulative contribution rate of the first k principal components reach 85% or the characteristic value is greater than 1, the first k principal components basically contain all the information contained in the indicators. By calculating we get the following results.

Table 1 Total Variance Explained

Element	Initial Eigenvalue			Extraction Sums of Squared Loadings		
	Total	Variance (%)	Cumulative Variances (%)	Total	Variance (%)	Cumulative Variances (%)
1	3.405	56.748	56.748	3.405	56.748	56.748
2	2.334	38.902	95.649	2.334	38.902	95.649
3	0.261	4.351	100.000			
4	3.105E-16	5.175E-15	100.000			
5	1.072E-16	1.786E-15	100.000			
6	-1.386E-16	-2.310E-15	100.000			

From Table 1 we can see that the cumulative contribution rate of the first two principal components was 95.649%, which is greater than 85%, so we extracted the first two principal components.

Table 2 Component Matrix

Component Matrix		
	Principal Components	
	1	2
Zscore(Investment in Public Education)	-0.173	0.979
Zscore(Industrial Structure)	0.887	0.456
Zscore(Gross Enrollment Rate)	0.944	-0.172
Zscore(Investment in Research)	0.699	-0.698
Zscore(the Rate of Unemployment)	0.927	-0.064
Zscore(Ratio of Education Expenditure to GDP	0.590	0.803

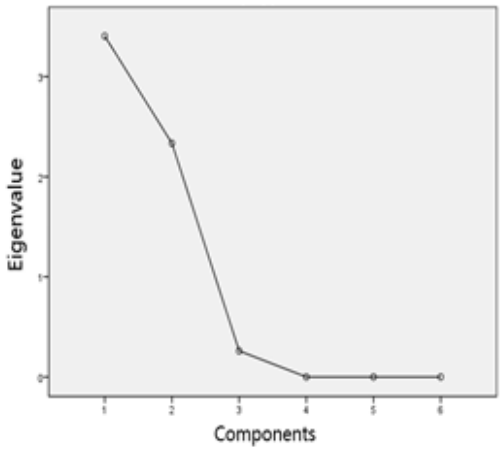

Figure 5. Screen Test

From Figure 5 we can see that two principal components have been extracted. From Table 2, we can see that industrial structure, gross enrollment rate, research expenditure and the unemployment rate have a large correlation coefficient with principal component 1, so they are classified as the principal component 1. Meanwhile, public spending on education and education expenditure have a large correlation coefficient with principal component 2, so they are classified as principal component 2.

Employment rate after graduation is also one of the important indicators to measure higher education, a healthier higher education system should enable students to be recognized by society and the market after completing higher education, which shows that students' professional ability and soft power have been well cultivated. Therefore, the post-graduation employment rate can also reflect the situation of the education system.

2.2 Analytic Hierarchy Process

To determine the weights of each of the three sections, we use Analytical Hierarchy Process (AHP) to determine the weights.

The analytic hierarchy process (AHP) adopted in this paper is the most widely used method in weight evaluation, but its objectivity is poor. However, the weight determined by the objective method cannot fully in line with its importance in practice. Although the subjective method is in the process of determining the weight of the indicators, it can reflect the difference of the relative importance of the three indicators.

As for policy and output, policy reflects the importance attached to higher education at the national social level, and output is a result of higher education, so we believe that policy accounts for a relatively high proportion in two aspects. In conclusion, we get the matrix.

Calculating the maximum eigenvalue and normalizing the corresponding eigenvector, we obtain the weights of each section. The sections we consider together with their weight is shown in Figure 6 below.

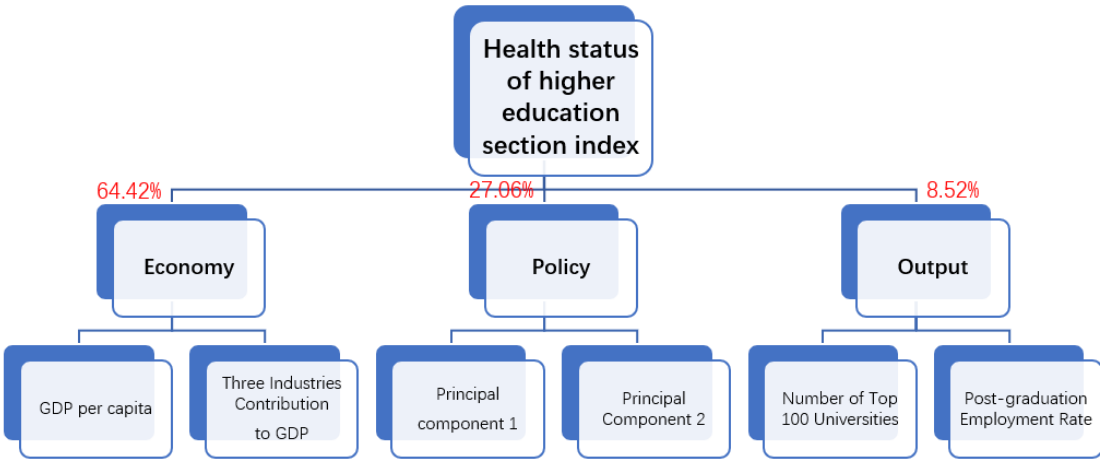

Figure 6. Sections and Their Weight

To test the consistency of the matrix, we calculate the Consistency Ratio (CR), which is defined as the ratio of Consistency Index (CI) to Average Random Consistency Index (RI). And $\mathrm{CI} = \frac{\lambda_{max} - n}{n-1}$; The larger Ci is, the worse the consistency of the judgment matrix is. When Ci is zero, the judgment matrix has complete consistency. The smaller Cr is, the better the consistency of the judgment matrix is. In general, when Cr ≤0.1, the judgment matrix is considered to have satisfactory consistency.

In this paper, n=3, $\lambda_{max} = 3.0536$, CI=0.0268, CR=0.0516< 0.1, so the consistency of the matrix is confirmed.

3. Result

From the results, we can see that the current health scores of higher education in the four countries from high to low are the United States, Japan, China and Vietnam. By analyzing the data, we can also find that the United States has a lot of room for improvement in policy. So next we will propose improvement measures for the United States in terms of policy.

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