Research On Evaluation of Higher Education Systems Based on Analytic Hierarchy Process

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Abstract: This paper analyzes the status quo based on the epidemic situation after building an evaluation model for higher education's healthy and sustainable development. This paper argues that sustainability is a factor in health status included and uses the indicator of future growth potential, mainly using AHP to establish a higher education health evaluation model. From the perspective of the universities' exterior and interior, this paper separately screened 7 indicators, including the proportion of education expenditure and the highly educated population and 9 indicators, including the number of universities and the number of teaching staff per capita. Through the analytic hierarchy process, the weight of each indicator is calculated, and the indicators with a contribution rate of more than 80% are selected as future development potential indicators. Then take the higher education's external, internal, and future development potential indicators as input, and higher education's healthy and sustainable development evaluation as output, constructing the AHP model. It is found that the more developed the economy is, the higher the evaluation score is. In the past decade, the scores in European countries are generally ahead of Africa and South America. At the same time, this article uses China as an example and points out problems such as the discontinuous development of education.

1. Introduction

A higher education system is an essential element in a nation's efforts to educate its people in the post-secondary level further [1], and, therefore, it has the significance of training people for both the country's economy and industry [2]. In the past century, the rapid development of higher education has become the main trend globally. There are multiple approaches to higher education worldwide [2], whereas each system shows its merits and drawbacks, especially under the circumstance of COVID-19.

Scholars represented by Martin Trow have conducted research on education in the popularization stage of higher education [4], who believe that higher education in the popularization stage will sharpen a new relationship between the country, education, and society. Actions must be taken to improve the system further [5]. Thus, establishing a model to evaluate and predict the health and sustainability of a higher education system is indispensable [6]. This paper adopts the analytic hierarchy process (AHP) to establish a higher education health evaluation model and analyzes the current situation of health and sustainable development [7].

2. Establishment of models

2.1. Data Processing

In order to measure the health and sustainability of the higher education system in a country, we have inquired two indicators, including internal and external factors, from statistical yearbooks and relevant statistical websites of various countries. The internal factors of post-secondary institutions include the number of universities (or colleges), the number of enrolled students, the number of students at universities, the number of graduates, the employment rate, the number of teaching staff,

the number of teaching staff per capita, the number of scientific research outcome (including the number of scientific papers, journal articles and patents), and the number of scientific research outcome per capita. External factors contain societal donations for education, tuition, and miscellaneous fees, comprehensive institution rankings (QS World University Rankings Top 100), government education expenditures, education expenditures as a proportion of total fiscal expenditures, population with higher education qualifications, population with higher education qualifications as a proportion of the total population. These two main indicators interact and form a higher education health evaluation system.

2.2. Establishment of AHP Model

2.2.1. Establishment of Hierarchical Structure

In order to organize and hierarchize the influential factors included in the problem, a hierarchical structure model is constructed. In this model, the sophisticated problem is broken down into several elements, where there exists a certain relationship among different levels; the elements of the previous level dominate the elements of the next level. Levels can be further divided into the following three categories: the highest level, the middle level, and the lowest level, whereas the established hierarchical structure has the following characteristics [8]:

a. In the whole structure, the number of layers is not limited

b. There is only one element at the highest level, and generally, no more than 9 elements dominate by each element

c. There is a dominating relationship from top to bottom, which is represented by a straight-line segment

d. Structures with sub-levels can introduce virtual elements

2.2.2. Constructing a pairwise price comparison judgment matrix

We demonstrate which dominating factor is significant and the discriminant matrix according to the specific situation. A matrix which such property is called the reciprocal matrix and the weight table is given in Table 1.

$$a_{ij} > 0, a_{ij} = 1/a_{ji}, a_{ii} = 1, i, j = 1,2,3,\ldots, \ n, \tag{1}$$

2.2.3. Establishment of Hierarchical Structure

Take the normalized arithmetic average of the n column vectors of the discriminant matrix approximately as the weight vector that is:

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, (i = 1,2,3,...,n) \tag{2}$$

Table.1. AHP Weight Explanation Table

SCALING	EXPLANATION
1	u_i and u_j have equal significance
3	u_i is slightly more significant than u_j
5	u_i is more significant than u_j
7	u_i is highly more significant than u_j
9	u_i is highly significant than u_j
2, 4, 6, 8	The significance ratio of $u_{i\ and}$ u_j is between the above two adjacent statements
RECIPROCAL	If the ratio of the significance of u_i to u_j is a_{ij}, then the ratio of u_j to u_i is $a_{ji}=1/a_{ij}$

Each vector of the discriminant matrix is normalized after geometric averaging, and the obtained column vector is approximated as a weighting vector:

$$\omega_i = \frac{(\prod_{j=1}^{n} a_{ij})^{\frac{i}{n}}}{\sum_{k=1}^{n}(\prod_{j=1}^{n} a_{kj})^{\frac{i}{n}}} \tag{3}$$

Finally, find the maximum eigenvalue and right eigenvector of the matrix, and finally, use the normalized eigenvector as the sorting weight vector.

2.2.4. Consistency check

Calculate the consistency index:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{4}$$

Find the corresponding average random consensus index RI is shown in Table 2.

Calculate the consistency ratio:

$$CR = \frac{CI}{RI} \tag{5}$$

When CR<0.1, the consistency of the matrix is considered acceptable.

Table.2. AHP index table

AHP Index Table										
Matrix order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table.3. Internal element weight coefficient table

C1	C2	C3	C4	C5	C6	C7	C8	C9	CI_1	CR_1
0.02898	0.02898	0.01449	0.08695	0.17391	0.11594	0.14492	0.17391	0.7318	0.0137	0.009

Table.4. External factors weight coefficient table

C10	C11	C12	C13	C14	C15	C16	CI_2	CR_2
0.07692	0.03846	0.11538	0.15384	0.19230	0.19230	0.23076	0.0383	0.0281

2.3. Establishment of post-secondary institutions health evaluation model

2.3.1. Determination of evaluation indicators

The model established in this paper selects two kinds of internal factors (B1) and external factors (B2), including the number of universities (C1), Number of college enrollment (C2), number of students (C3), number of graduates (C4), employment rate (C5), number of teachers (C6), number of teachers per capita (C7), number of scientific research results (C8) and per capita scientific research achievement (C9) internally and social donation education funding (C10), tuition and fees (C11), a comprehensive ranking of universities (C12), education expenditure (C13), the proportion of education expenditure (C14), population with higher education (C15) and proportion of the population with higher education (C16) externally.

2.3.2. Construction of Index Weight System

Use the analytic hierarchy process to pairwise compare the significance of the index factors of the first-level system, the second-level, and the third-level subsystems in the evaluation system of each country's hierarchical evaluation model, then construct a discriminant matrix, and obtain the following index weights as shown in Table 3 and Table 4.

According to the two tables calculated above, CR_1=0.009<0.1, CR_2=0.0281<0.1. Hence, both discriminant matrices passed the consistency test.

2.3.3. Eliminate the influence of dimensions

Since the dimensions of the original data are different, they cannot be directly calculated by the mathematical model. In order to facilitate our processing, the selected data is processed without dimension, while the method used is the normalization method.

Transformation sequence x1, x2,..., xn:

$$y_i = \frac{x - \bar{x}}{s}, here \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i, s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{6}$$

So the mean of the new sequence y1, y2,...yn is 0, and the variance is 1, and it is dimensionless.

2.3.4. Calculate the composite weight of each layer element to the target layer

After the weight of each index and the original data of the index are dimensionless, the comprehensive evaluation is obtained by calculating the comprehensive value.

Use linear weighted sum calculation model to calculate:

$$B = \sum \omega_i A_i \tag{7}$$

Among them ω_i is the evaluation value of i of the index of the next layer and A_i is the corresponding weight.

In this way, starting from the third-level indicators, calculate the indicators of the upper layer, and then multiply the weight of the upper layer by the evaluation value, and calculate the top index value through linear weighting, we could obtain the individual evaluation score.

3. Analysis of results

According to the evaluation model, we first evaluate and analyze the data of the past 20 years in China to verify the model's reliability. With the internal and external weights being 0.5, the 20- year score is shown in Figure.

From the above analysis, it can be seen that the model integrates 9 indicators of external factors and 7 indicators of school external factors. The data obtained is roughly in line with the development of higher education in China. With the continuous development of the economy and people's emphasis on education, composite scores have increased gradually since 2000.

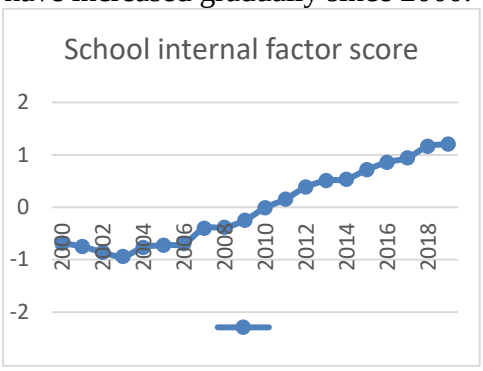

Figure 1. Line chart of changes in internal factors of Chinese institutions in the past 20 years

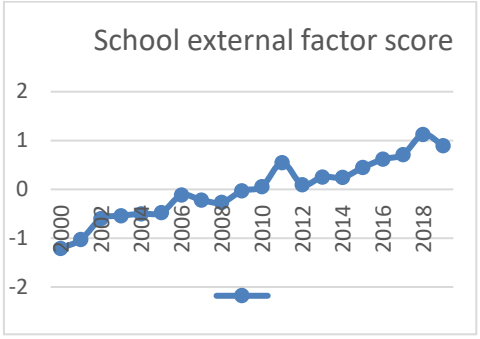

Figure 2. Line chart of changes in external factors of Chinese institutions in the past 20 years

This article has derived the above national higher education system evaluation model by analyzing data from the past two decades using the AHP model. In order to better explain the evaluation standard of the model, we have selected India, South Africa, Colombia, Italy, France, Sweden, and Bulgaria for further evaluation and analysis. The selected countries involve developed and developing countries from economic development. On the other hand, it involves three continents, including Europe, America, and Africa, geographically. Therefore, this study evaluated the higher education systems of the above seven countries in the past ten years.

It can be concluded from Figure 4 that from the perspective of economic development, the more developed the economy, the higher the evaluation score of the higher education system. From the recent ten years of evaluation score changes, Sweden's score has been rising steadily, and the evaluation is ahead of other countries,

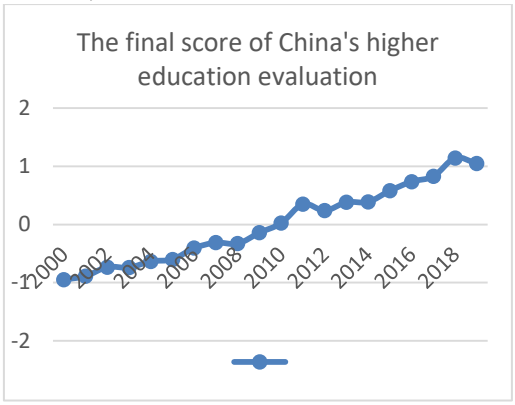

Figure 3. Line chart of the comprehensive score changes of China's higher education in the past 20 years

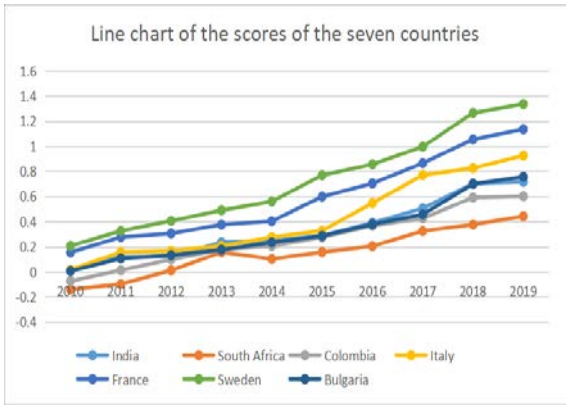

Figure 4. Line chart of the scores of seven countries

Which may benefit from the fact that about 25% of the people in Sweden have obtained at least associate or undergraduate degrees with a special academic atmosphere.

Due to the economic development and religious discrimination in most parts of Africa and South America, the scores of European countries are generally higher than that of Africa and South America. Overall, this scoring system could reflect the development of the higher education system in a country.

4. Conclusion

This paper analyzes the status quo based on the epidemic situation after building an evaluation model for higher education's healthy and sustainable development. It is found that the more developed the economy is, the higher the evaluation score is. In the past decade, the scores in European countries are generally ahead of Africa and South America.

Through the model's evaluation of China's higher education in the past 20 years, it can be seen that with the continuous growth of the economy, the increase in disposable income per capita, and the new

generation of Chinese youth's changing views on education, China's higher education has been steadily improving. Nevertheless, the initiation of China's higher education has been seriously lagging, and the development is discontinuous to some extent and a severe lack of government spending in higher education for more than a century. Due to these reasons, the overall strength of China's higher education is far lower than that of European and American countries. The next step should be to improve the student financial aid system to ensure that students with financial difficulties do not lose access to higher education due to financial difficulties. With the disruption of the epidemic last year, offline education has been greatly affected, and most of the learning has been shifted online. It is necessary to change their education methods and improve the quality of online education.

References

[1] Wei hong. The diversification of education evaluation to [J]. Journal of henan education (teacher education), 2021 (04): 11-13. DOI: 10.16586 / j.carol carroll nki/g4.2021.04.006 41-1033.

[2] Weide Qiao. Research on construction of Evaluation System of Innovation and Entrepreneurship Education in Colleges and Universities [J]. Journal of Nanjing Radio & TV University, 2021 (01): 28-36.

[3] Elton, L. and Cryer, P., 1994. Quality and change in higher education. Innovative Higher Education, 18 (3), pp.205-220.

[4] Michael Kariwo, Tatiana Gounko, Musembi Nungu. A Comparative Analysis of Higher Education Systems - Issues, Challenges and Dilemmas [M]. Brill Sense: 2014-01-01.

[5] Su, M., 2016. Analytic Hierarchy Process Evaluation of English Teaching Quality in Application-Oriented Universities. International Journal of Simulation: Systems, Science & Technology.

[6] YunTao Pan. Research on The Quality of Graduate Education from The Perspective of Whole Process Quality Management [J]. International Journal of Social Sciences in Universities, 2020, 3 (4).

[7] Yonghong, A., Yang, B., Fan, Y. and Gang, Z., 2012. The Application of Modified Delphi-AHP Method in the College Students' Comprehensive Quality Evaluation System. International Journal of Information and Education Technology, pp.389-393.

[8] YUE, Y., 2012. The AHP Model of Evaluation on Quality-Oriented Education in College English Teaching. International Journal of Education and Management Engineering, 2 (5), pp.37-42.