ISSN: 2688-9323

Research on the Evaluation of the Health and Sustainability of Higher Education Systems

Luyue Gao

School of Chongqing University of Posts and Telecommunications, Chongqing 400065, China

gaoluyuework@126.com

Abstract

This article explores how to measure and evaluate the health of the higher education system in various countries. It also proposes a healthy and sustainable development goal for the higher education system of each country, and proposes a set of targeted policies to shift the health of the country's higher education system from its current state to the target state. In this paper, PCA, K-means clustering, and GM (1,1) prediction are used. This study builds Health Evaluation Model to assess the health of a system of higher education. Health Classification Model to identify a healthy and sustainable state for a given nation's higher education system, and then propose policies to migrate a nation from its current state to proposed state.

Keywords

PCA; GM (1,1) Prediction; K-means Clustering; Higher Education.

1. Introduction

1.1. Background

A system of higher education is an important element in a nation's efforts to further educate its citizens beyond required primary and secondary education, and therefore has value both as an industry itself and as a source of trained and educated citizens for the nation's economy [1]. As we look around the world from Germany to the United States to Japan to Australia, we see a variety of national approaches to higher education, with each of these nations not only educating their own students, but also drawing large numbers of international students every year. Each of these national systems of higher education has its strengths and weaknesses, and in the wake of adjustments required during the current pandemic, nations have had the opportunity to reflect on what is working and what could be even better. However, change is often difficult. The institutional changes required to advance any system require policies implemented over an extended period in order to reach a more healthy and sustainable system.

To solve the problem, I develop a model to measure and assess the health of a system of higher education at a national level, to identify a healthy and sustainable state for a given nation's higher education system, and to propose and analyze a suite of policies to migrate a nation from its current state.

1.2. Analysis

Firstly, collected indicator data for 6 recent years from 10 countries and standardized them. Then KMO and Bartlett's Test tests were performed to make the linear correlation between their indicator variables conform to the model requirements. The two principal components and their weights and combined score expressions were derived. The indicator data of the 10 countries were then substituted into the principal component analysis model to find the final composite score, and the results obtained were analyzed according to the combined meaning of their indicator weights, and Korea was found to have a low score in this model, and was

ISSN: 2688-9323

considered to have more room for improvement. I substitute the 2015-2019 indicator data of the selected country into the model one can get the corresponding higher education health evaluation index. Through the GM (1,1) prediction model, predict the achievable, short-term future Reasonable target value, as the country's future vision. The higher education health evaluation index of sample countries is processed by K-means clustering method, and three types of A, B, C are obtained to measure the higher education health status of each country, and A, B, C represent excellent and poor respectively. I select the index with the largest fluctuation over the years from the six major indicators that affect the health status, as an adjustment index, and fix other indexes unchanged in order to obtain the target year's index value. And formulate targeted measures and implementation timetable. Finally, I build a policy effectiveness evaluation model, use the membership function to measure the health and conclude that the policy is effective. It also considers the possible impact of the actual implementation of the policy on schools, society, etc. and recognizes that it is difficult to increase funding for higher education.

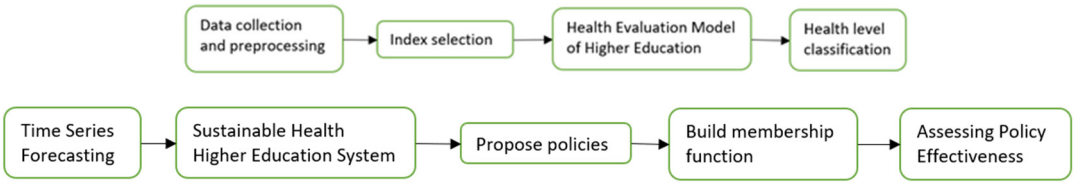

Fig 1. Problem Analysis Flow Chart

2. Data Processing

2.1. Index Selection

To assess the health of each country's higher education system, six indicators were chosen: the number of universities, the number of QS top 200 universities, university enrollment, the number of international students, the percentage of GDP spent on higher education, and the number of SCI publications.

Number of universities: represents the level of sophistication of the country's higher education infrastructure; Number of universities in the top 200 of the QS ranking: represents the overall level of higher education in the country; College enrollment: represents the access to higher education for the citizens of the country; Number of international students: represents the international presence of higher education in the country; Share of GDP spent on higher education: represents the cost the country spends on higher education; Number of SCI publications: represents the level of research in the country.

The above six indicators evaluate the expressiveness of higher education in terms of cost, access, educational level, and international influence, and can provide a comprehensive measure of the health of a country's higher education system.

2.2. Data Collection

To construct the health evaluation model of higher education system, we collected the data values of 5 developed countries and 5 developing countries (Korea, USA, UK, Canada, Japan, China, Russia, Malaysia, South Africa, and Thailand), a total of 10 countries on these 6 major indicators as the base data.

ISSN: 2688-9323

Table 1. Data source collation

Database Website	Descriptions
http://kostat.go.kr/portal/korea/index.action	Korea
https://nces.ed.gov/	USA
https://www.ons.gov.uk/	UK
https://www.statcan.gc.ca/	Canada
http://www.stat.go.jp/	Japan
http://www.stats.gov.cn/	China
https://rosstat.gov.ru/	Russia
http://www.statistics.gov.my/	Malaysia
http://www.statssa.gov.za/	South Africa
http://www.nso.go.th/sites/2014	Thailand

2.3. Data Standardization

Due to the different units of each indicator, to ensure the subsequent analysis, we need to eliminate the effect of the magnitude of the raw data, which means to standardize: convert each indicator value x_{ij} into a normalized indicator $\widetilde{x_{ij}}$ .I have selected a total of m indicator variables: $x_1, x_2, \dots, x_m$, with a total of n evaluation objects (countries), and the jth indicator of the ith country takes the value x_{ij}. [2]

$$\widetilde{x_{ij}} = \frac{x_{ij} - \mu_j}{s_j} \quad (i = 1,2, \dots, n; j = 1,2, \dots, m)$$

$$\mu_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}\,, s_j = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij} - \mu_j\right)^2\,, (\,\mathrm{j} = 1,2, \dots, m)$$

Table 2. Standardized indicators by country

Nation Index	Korea	USA	UK	Canada	Japan	China	Russia	Malaysia	South Africa	Thailand
Number of international students	0.27	3.75	1.52	1.67	0.95	1.64	0.87	0.51	0.98	0.01
University admission rate	4.20	3.82	2.56	2.98	2.22	2.12	3.68	1.72	0.83	2.00
Number of SCI	0.28	3.03	0.75	0.42	0.42	2.30	0.21	0.01	0.02	-0.02
Number of universities	0.07	3.18	0.04	0.00	0.51	1.96	0.49	0.43	0.01	0.16
QS top 200 universities	0.41	3.25	1.86	0.41	0.62	0.41	-0.01	0.20	-0.01	-0.08
Percentage of GDP spent on higher education	5.35	5.24	5.69	5.69	3.61	4.13	3.72	4.90	6.98	4.20

ISSN: 2688-9323

3. Model Building

3.1. Evaluation Model of Higher Education Health Level

The six higher education health-related indicators collected were entered into Excel for data collation and logical cleaning, and KMO and Bartlett's Test circular tests and principal component analysis were performed using SPSS.

First, the data of the six higher education-related indicators for each country were entered into SPSS26.0 and then tested to obtain Table 3, which was used to perform KMO and Bartlett's Test tests on the data and to determine the linear correlation between the indicator variables [3]. The principal component linear results are as follows:

Table 3. Component Score Coefficient Matrix

Index	Component	
	1	2
Number of international students	0.288	-0.145
University admission rate	0.058	0.409
Number of SCI	0.255	0.069
Number of universities	0.229	0.155
QS top 200 universities	0.269	-0.114
Percentage of GDP spent on higher education	0.126	-0.752

According to Table 3, the linear combinations of the two principal components are:

$$y_1 = 0.288 * x_1 + 0.058 * x_2 + 0.255 * x_3 + 0.229 * x_4 + 0.269 * x_5 + 0.126 * x_6$$
$$y_2 = -0.145 * x_1 + 0.409 * x_2 + 0.609 * x_3 + 0.155 * x_4 - 0.114 * x_5 - 0.752 * x_6$$

Based on the first principal component y_1 and the second principal component expressiony_2 and their contribution rates, a model for the composite evaluate score of the principal components is constructed as follows.

$$Z = 0.746 * y_1 + 0.254 * y_2$$

After standardizing the collected source data and substituting the above formula, the results of the composite higher education score for each country were obtained as shown in the following table.

The countries with composite scores less than zero were Malaysia, Thailand, and South Africa. The composite scores of these sections were less than zero, indicating that their higher education health levels were below average, with South Africa having the lowest score.

Countries with composite scores equal to or greater than zero include the United States, China, the United Kingdom, Russia, Japan, Canada, and South Korea. These countries have above-average levels of higher education health, with the United States scoring the highest.

ISSN: 2688-9323

Table 4. Results of the Composite Score of Higher Education by Country

Country	First Principal Component(y1)	Second Principal Component(y2)	Composite Score(z)
USA	4.339	-0.954	2.995
China	2.261	-0.822	1.478
UK	2.006	-3.204	0.683
Russia	1.095	-1.209	0.510
Japan	1.247	-1.678	0.504
Canada	1.585	-3.098	0.396
Korea	1.191	-2.210	0.327
Malaysia	1.019	-3.002	-0.002
Thailand	0.658	-2.323	-0.099
SouthAfrica	1.217	-5.034	-0.371

The health of higher education varies widely by country. Regions such as the United States and China are far ahead, mainly in terms of Number of international students, Number of universities, QS top 200 universities, etc. However, regions such as Thailand and South Africa are relatively lagging behind in higher education, mainly in terms of University admission rate, Number of SCI, Percentage of GDP spent on higher education, etc. These regions are in greater need of government investment in higher education. These regions need more government investment in higher education, such as the establishment of schools and the improvement of national admission policies. [4]

3.2. Model for Predicting National Education Vision

Korea, a developed country, scored low in this comprehensive evaluation score, indicating that there is more room for improvement in higher education in Korea. Korea has more room for improvement in the healthy development of higher education, so South Korea is chosen as the target country for further research.

Substituting the sample indicator data of South Korea from 2015 to 2019 into Model one, the corresponding 2015-2019 South Korean higher education health evaluation index is obtained. Through health evaluation indexes, the GM (1,1) model is established. The specific steps are as follows: Calculate a cumulative sequence $x^{(1)}$. Build matrix B, Y, Find the inverse matrix $(B^TB)^{-1}$. According to $\widehat{U} = (B^TB)^{-1}B^TY$, find $\hat{a}$and$\hat{u}$. $z^{(i)}(k+1) = \left[z^{(i-1)}(1) - \frac{u}{a}\right]e^{-ak} + \frac{u}{a}$, calculate predicted value. Select the residual test to test the accuracy of the data: $E(k) = x^{(0)}(k) - \hat{x}^{(0)}(k) = 0.12 < 0.2$.[5]

Table 5. Prediction result meets the accuracy test requirements.

Country	Predicted value
Korea in 2020	0.3649
Korea in 2021	0.4081
Korea in 2022	0.4527
Korea in 2023	0.4987
Korea in 2024	0.5462

3.3. Model Classification Model

Let the higher education health evaluation index of the sample countries be a matrix Z. Let Korea's higher education health evaluation index for the next five years is a matrix , Among these 15 samples, we divide them into three types to measure health: excellent, good, and poor

ISSN: 2688-9323

according to the distribution law of the data. Countries with excellent health are classified as Class A, and countries with good health are classified as Class A. It is classified as B, and unhealthy countries are classified as C. Using K-means clustering method to cluster the higher education health evaluation index to obtain three types.

The higher education health evaluation index of 10 countries is imported into SPPS, and 3 cluster centers are calculated by K-means clustering method, and 3 types of higher education development health status are obtained through cluster centers, namely A, B and C The categories represent excellent, good, and poor respectively. The classification results of the health status of higher education in each country are as follows:

Table 6. Classification of Higher Education Health Status

Country	Type
South Africa	C
Thailand	C
Malaysia	C
Korea	B
Canada	B
Japan	B
Russia	B
UK	B
China	B
USA	A
Korea in 2020	B
Korea in 2021	B
Korea in 2022	B
Korea in 2023	B
Korea in 2024	B

3.4. Targeted Policies and Implementation Timeline

In order to migrate the health of the higher education system in our selected countries from the current state to the proposed state, we will develop adjustment policies in the relevant areas and draw a timetable for achieving them, starting from six major areas: the number of international students, university admission rate, the number of SCI, the number of universities, QS top 200 universities, percentage of GDP, spent on higher education.

As the country's indicator values in these six areas fluctuate differently each year, which means that the ease of policy adjustment in each area is different. For example, if the fluctuation of an indicator is small in all years, it means that it is more difficult to optimize this indicator and the effect of implementing targeted policies on it is less effective; if the fluctuation of an indicator is larger in all years, it means that this indicator is easy to be changed and the implementation of targeted policies can It is more effective to influence it to a greater extent. In order to facilitate the development of subsequent policies, we first select the indicators that are easier to change.

I collected data on these 6 indicators in South Korea from 2015 to 2019, and calculated their average volatility $\overline{\Delta_j} = \frac{1}{n}\sum_{k=1}^{n}\Delta_{jk} \quad (k = 1,2,3,4; j = 1,2,\ldots,6)$.

The calculated results are as follows:

ISSN: 2688-9323

Table 7. Index Average fluctuation range

Index	Number of international students	University admission rate	Number of SCI	Number of universities	QS top 200 universities	Percentage of GDP spent on higher education
Average fluctuation range	-0.044412311	-0.15401	0.678103	0.51031	0	0.690186

The current state as the health of the higher education system in 2019 and the ideal state as the proposed health of the higher education system for each year from 2020-2024. To make the policy implementation more targeted and to optimize the effect, we fixed the other five indicators and adjusted the indicator of GDP share of higher education funding to reach the proposed ideal state of the system.

$$Z_y' - Z_{2019} = COEF(x_{y6}' - x_6)$$

Z_y' is the health index of the system for each year from 2020-2024, and Z_{2019} is the current health index of the system in 2019. COEF is the conversion relationship between indicator x and composite evaluation value Z, x_6 is the value of the higher education funding GDP share indicator for 2019, and x_{y6}' is the value of the higher education funding GDP share indicator to be sought for the target year.

I substitute the available data into the equation to calculate the target for each year:

Table 8. Implementation Timeline

Year / Index	2020	2021	2022	2023	2024
Ideal Health Index	0.3649	0.4081	0.4527	0.4987	0.5462
X6 target value	2.4831	2.9284	3.3882	3.8623	4.3519
X6 increase over previous year	0.5579	0.4453	0.4597	0.4742	0.4896

From the above table, it can be seen that the Korean higher education system needs to increase the national investment in higher education funding year by year if it is to reach the ideal health status value set annually. The proposed policy is to increase the GDP share of higher education to the standardized value of 2.48 and 0.55 in 2020, to the standardized value of 2.93 and 0.0.44 in 2021, and to the standardized value of 2.93 and 0.0.44 in 2021, and to the standardized value of 4.35 and 0.48 in 2024. The standardized value is 0.48.

Higher education funding is the foundation of higher education development. Adequate funding can provide better educational infrastructure, more access to education, more research projects, etc., and in a way can measure how much a country values education. National funding for higher education could perhaps be improved by:

(1) Improve the efficiency of the use of research funds, and set up special research fund supervisory agencies in each university to ensure that research funds are used efficiently.

(2) Optimize the structure of using higher education funds and pay attention to the coordinated development of economic growth and the scale of higher education.

(3) Increase the overall investment in higher education by increasing social investment, for example, encouraging enterprises, units and individuals to donate to colleges and universities, and giving moderate tax exemption preferential policies.

ISSN: 2688-9323

Improve the mechanism of higher education input: government input is the main one, educated people share reasonably, and improve the mechanism of raising funds through other channels.

4. Summary

In this study, I found six indicators that affect the evaluation of higher education, and used the principal component analysis method to obtain the evaluation model of the health status of higher education in each country. This model can get the score of each country, and finally get the comprehensive score ranking of ten countries: United States, China, Britain, Russia, Japan, Canada, South Korea, Malaysia, Thailand, South Africa. After comparison, it is found that South Korea has a lot of room for improvement, so South Korea is selected as the object of further analysis, and the future development goal value of South Korea is predicted through the GM (1,1) model, which is regarded as the goal of the health development of South Korea's higher education. In order to make South Korea's higher education develop towards its goals, a series of targeted measures are proposed to promote the development of South Korea's higher education.

References

[1] Bo Zeng, Shuliang Li, Wei Meng Grey Prediction Theory and Its Applications[M] Science Press 2020 9787030648204.

[2] Dengyun Wei, Wenjun Zhang. Standardization analysis of original data in the application of principal component analysis [J]. Journal of Anhui Normal University (Natural Science Edition), 2018, 41(02): 189-194.

[3] Shoukui Si. Mathematical modeling algorithm and program [M]. National Defense Industry Press: Beijing, 2007: 596-605.

[4] Wanju Tao, Yijuan Lv, Jiaojiao He, Wang Li. Application of Principal Component Analysis in the Analysis of the Implementation Rate of Public Hospital Budget Expenditure[J]. Modern Business and Trade Industry, 2021, 42(09): 87-89.

[5] Kaiyou Wang, Dingyuan Chen, Discussion on the Grey Modeling of GM (1, 1) [J]. Natural Science Foundation Project, 2008,08,15.