ISSN 2522-6398 Vol. 4, Issue 9: 1-5, DOI: 10.25236/FER.2021.040901

Analysis on the health level and sustainability of Higher Education——Evaluation based on AHP and DEA model

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Abstract: *This paper presents a model system to measure the health status and sustainability of higher education in different countries. We set up two primary models to measure the health status and sustainability of national higher education. According to the data processed by the model, we put forward targeted policy suggestions and implementation plan suggestions for the current health level sustainability of higher education in China, a developing country. This model has the ability to process and measure the health status and sustainability of higher education in different countries according to the representative index data of higher education available in different countries, and put forward the target state and other issues.*

Keywords: *Data Envelopment Analysis Model, Analytic Hierarchy Process Model, time series regression*

1. Introduction

In this new era of rapid development of science and technology, talents and science and technology are extremely important, and the cultivation of higher talents is a problem that every country attaches importance to. With a healthy and sustainable higher education system, a country can train talents economically and effectively, so that talented people will not be submerged and capable people will shine. A healthy and effective higher education system is the strong backing of the country and can help the country develop rapidly in all aspects.

2. Mathematical Models

2.1 Analyze health condition of higher education system

2.1.1 Model preperation

(1) DEA model description

Assume that each DMU has m kinds of outputs and s kinds of inputs, $x_j = (x_{1j}, x_{2j}, \dots\dots, x_{mj})^T, y_j = (y_{1j}, y_{2j}, \dots\dots, y_{sj})^T$ indicate the outputs and inputs of decision j (1,2,....n) respectively; $v = (v_1, v_2, \dots\dots, v_m)^T$, $u = (u_1, u_2, \dots\dots, u_s)^T$, they are the weight vectors corresponding to m inputs and s outputs, which satisfies $v \in E^m, u \in E^s$, making the efficiency evaluation function of decision making unit:

$$h_j = \frac{u^T y_j}{v^T x_j} 1, \ \ j = 1,2, \dots\dots, n \tag{1}$$

Targeting the efficiency evaluation function $h_j = \frac{u^T y_j}{v^T x_j} \le 1$ of $j_0 (1 \le j_0 \le n)$ decision making unit DMU_{j0}. Then we establish the following function:

$$max h_{j0} = \frac{u^T y_0}{v^T x_0} \tag{2}$$

$$s.t. \begin{cases} h_j = \frac{u^T y_j}{v^T x_j} \le 1, \mathrm{j} = 0,1,2, \dots\dots, \mathrm{n} \\ v = (v_1, v_2, \dots\dots, v_m)^T \ge 0 \\ u = (u_1, u_2, \dots\dots, u_s)^T \ge 0 \end{cases} \tag{3}$$

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Using the Chames-Cooper transformation, it can be programmed as an equivalent linear programming form. Let:

$$t = \frac{1}{v^T x_0} > 0, w = tv, \mu = tu \tag{4}$$

Then the distributed programming can be divided into the following linear programming (P).

$$s.t. \begin{cases} max\mu^T y_0 \\ w^T x_j - \mu^T y_j \geq 0, \ \ j = 0,1,2, \dots \dots, n \\ w^T x_0 = 1 \\ w \geq 0, \mu \geq 0 \end{cases} \tag{5}$$

Its dual programming (d) is as follows:

$$s.t. \begin{cases} min\theta \\ w^T x_j - \mu^T y_j \gamma_j \geq 0, \ \ j = 1,2, \dots \dots, n \\ \sum_{j=1}^{n} \gamma_j y_j \geq y_0 \\ \gamma_j \geq 0 \\ \theta \ has \ no \ restriction \end{cases} \tag{6}$$

In this study, the team assigned each variable to AHP weight coefficient and brought it into the follow-up model to get the desired results.

(2) AHP model description

Analytic hierarchy process (AHP) determines the relative importance of each input-output factor by pairwise comparison, and determines the total order of relative importance of decision-making scheme.

Step1: The relationship between the input-output factors in the system is analyzed, and the hierarchical structure of the system is established

Step2: The importance of each element in the same level is compared in pairs with respect to the previous level, and the judgment matrix of pairwise comparison is constructed

Step3: The relative weights of the compared elements are calculated by the judgment matrix

Step4: The composite weights of the elements of each layer to the system objectives are calculated and sorted to obtain the weight index of each variable which can be used in the follow-up study of DEA model.

2.1.2 Country and variables chosen

(1) Input variables

For the input index in DEA model, we choose(1)higher education funds, (2)research funds, (3)the number of teachers, (4)the proportion of higher education, (5)the number of higher education institutions as indicators.

(2) Output variables

For the output indicators in DEA model, we choose (1) the number of undergraduate graduates, (2) graduated graduates, (3) international students, (4) gender ratio (female /male) (5) comprehensive scientific research quality as indicators.

2.1.3 Results

Table 1: The results of DEA model on chosen countries

countries	*techch*	*effch*	*pech*	*sech*	*tfpch*
Japan	1.000	1.088	1.000	1.000	1.088
Singapore	1.000	1.138	1.000	1.000	1.138
US	1.000	0.999	1.000	1.000	0.999
Korea	1.000	1.085	1.000	1.000	1.085
China	1.000	0.953	1.000	1.000	0.953
mean	1.000	1.050	1.000	1.000	1.050

techch: pure technical efficiency; effch: comprehensive efficiency; pech: change ratio of comprehensive efficiency; sech: scale efficiency; tfpch: change ratio of technical efficiency

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2.1.4 Analysis of the Result

According to Table 1:

1) Sech (scale efficiency) are all 1, which means that in our model, each country has reached the optimal production scale.
2) It is noted that the change rate of Japan, Singapore and South Korea is greater than 1, and the pure technical efficiency is equal to 1, which means that the utilization rate of the input resources is effective at the current technical level, and has a trend of gradually getting better; while although China and the United States have achieved effective utilization rate, China has shown a downward trend.
3) Comprehensive technical efficiency is the production efficiency of input factors of each DMU (country) in a certain (optimal scale). Because the comprehensive technical efficiency = tfpch * sech, we can see that in the current situation, every country is in the technical efficiency.

2.2 Analyze sustainability of higher education system

2.2.1 Model Preparation

(1) Autoregressive Model (AR (1))

Consider a time series $y_1, y_2, \ldots y_n$. P-order autoregressive model(shorted for AR(p)), which indicate that in the order, y_t is the function of the first p linear combination and their error term. Its normal mathematic model is

$$Y_{it} = \alpha_{i0} + \beta_{i0} x_{it} + Y_{it-1}, i, t = 1,2, \ldots \ldots, n \quad (7)$$

Where we choose the input variables as independent factors. As for the dependent variable, we have settled an index as representative.

According to a series of output indicators, we use AHP to give weight to the indicators and add them together to form a new variable index, which can be regarded as the indexation of output indicators output indexation. Therefore, the team uses the index variable and its change with time series to complete the research purpose of evaluating the sustainable development level of the higher education system in different countries.

2.2.2 AR (1) Model Result Statement

The index result are as follow:

Table 2: Output index of each country

countries	*Japan*	*Singapore*	*US*	*Korea*	*China*
2014	10.89119	3.890116	10.52448	9.609904	15.74025
2015	10.93124	4.002825	10.65016	9.546628	16.51444
2016	10.98073	4.136283	10.8387	9.427023	17.21364
2017	11.05565	4.811682	11.0508	9.276144	17.67584

After getting the index variable, linear regression model was used to analyze and visualize the index changes of Japan, Singapore, the United States, China and South Korea in the selected time span of 2014-2017. It can be concluded that except South Korea's poor performance and the index declining year by year, the other four countries show a good upward trend. Singapore's growth trend from 2016 to 2017 is relatively rapid, while the curve of the United States, Japan and China is relatively smooth. Noting that China's index growth in 2017 has slowed down compared with previous years, in order to conduct in-depth study and refer to the task requirements, the team selected China as the final research object, which is not the best but has a promising future. We will also put forward policy suggestions and Implementation Plan Suggestions in the following statements.

3. Analysis of China

3.1 Expected outcome of policies for higher education in China

According to the results of the model, we draw on the advantages of other countries' higher education system. It can be concluded that China can improve the efficiency of input versus output. Considering the actual factors and China's strength, to a certain extent, China can at least get close to the United States

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in terms of per capita education under the ideal state. Therefore, we boldly make the following explorations according to the data characteristics of other countries:

Assumption 1: To improve China's scientific research level within a certain extent of the increase of scientific research funds. The way can be to improve science and technology, improve efficiency, and promote ideas and so on.

Assumption 2: Increase the number of Chinese graduate students. That is to say, we should take publicity measures among the existing undergraduate students, increase the number of graduate students after graduation, increase the output and keep other data unchanged.

Assumption 3: Increasing the number of Chinese postgraduates and encouraging undergraduates to study abroad on the basis of 2 can increase international cultural exchanges and diversify our output.

Assumption 4: On the basis of 3, increasing the number of undergraduates in China will also further increase the number of postgraduates.

3.2 Policy advise and outcomes for higher education in China

3.2.1 Policy advise

(1) Research and development aspect

Strengthen scientific research and increase experimental hours; Increase scientific research funds and welfare of scientific research personnel; Encourage scientific research and innovation projects.

(2) Number of higher education talents aspect

Encourage undergraduates higher school students to further study;We should improve the scholarship system and grant system for postgraduatesc; Set up a reward mechanism for international students; Encourage domestic universities to communicate with overseas famous universities and set up more exchange programs and further education programs.

(3) Higher education infrastructure

To realize compulsory high school education and encourage more people to go to University; Encourage the upper class to set up specialized universities.

(4) Higher education system

Setting up self inspection system of Higher Education Institutions; Set up competitions and special internships.

3.2.2 Expected policy outcome

Table 3: Excepted policy outcome

gradua	*magradua*	*foreign*	*ratio*	*expand*	*qs*	*percentage increased of DEA*
				+	+	7.35%
	+					5.35%
	+	+				8.18%
+	+	+	+			0.94%

4. Conclusions

We have developed a set of model for evaluating each country’s higher education system, and practically apply in the above five countries. Then we reached a conclusion: China's higher education system has room for improvement.

According to the model’s result, we put forward the corresponding policy suggestions for China and its implementation schedule, finally analyzed policies’ expected effect on the basis of the reality in the transitional stage and final stag.

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ISSN 2522-6398 Vol. 4, Issue 9: 1-5, DOI: 10.25236/FER.2021.040901

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