Policy Selection and Evaluation for Higher Education of China, Based on Entropy Weight Method

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Abstract. The construction of higher education is the focus of China's future development. This paper is intended to provide advice on higher education policy in China. Along with this general objective, this study methodology use entropy weight model. We divided education policy making into 4 stages and 18 subdivision steps, and selected China and 16 other representative countries for analysis and policy reference. We set out detailed policies for each step of each stage and tested their effectiveness, explaining possible resistance in policy implementing. The value of this article lies in providing detailed directions for future high education policy making in China, and it can be used for reference by other countries with similar national conditions to China. The conclusion of this paper is that our policies can significantly improve the scores of China's higher education system in all aspects.

Keywords: Higher education policy · Entropy weight method · Education system of China

1 Introduction

With the rapid development of China, higher education has entered a stage of rapid development, and the process of comprehensive promotion of higher education has been accelerated. It is an important task of higher education to build a strong country in higher education and improve the quality of higher education in an all-round way. This essay aims to offer recommendations for China's higher education policy.

2 Review of Related Research

At present, scholars have done a lot of research on the current situation and future development of higher education in China, which can be divided into two aspects: comparing China's higher education power and studying China's education system. On the

X. Yuan et al. (Eds.): ICEKIM 2023, AHCS 13, pp. 2063–2073, 2023.
https://doi.org/10.2991/978-94-6463-172-2_230

one hand, Li Liguo et al. compared the gap between China's higher education and the world's developed higher education in scale, quality, investment and efficiency through the indicators of higher education power [1–3]. On the other hand, Shi Xiaoguang et al. puts forward the connotation of higher education in line with China's national conditions, and puts forward the thought of guaranteeing the fair development of higher education from the three dimensions of system, economy and culture [4, 5]. Zheng Yutong et al. put forward an interactive model of modern higher education based on a comprehensive study of China's higher education policies [6, 7]. Wang Zhuoyi et al. evaluated higher education systems in 42 countries based on the CIPP model and found that China higher education systems are belong to third tier among all samples. Similarity, higher education systems are rated poorly in nations with big populations and developing economies [8, 9].

However, the existing education policies ignore the validity test of education policies and weaken the resistance of education policies. This paper uses the quantitative method to put forward appropriate policies and test their feasibility and effectiveness.

3 Establishment of Evaluating System

Establish an educational evaluation system that can evaluate the health and sustainable development of higher education base on entropy weight method. We divided the educational evaluation into four stages and selected the following indicators to construct this system.

The first stage is context, including Population(A_1), CPI(A_2), Primary completion rate(A_3), GDP(A_4) and WGI(A_5).

The second stage is Input, including expenditure rate of the following indicators in GDP: Education($B_{1)}$, Tertiary Educational R&D(B_2), Initial government funding(B_4) and Government expenditure on tertiary education (B_3).

The third stage is process, including 4 different rates, Graduation(C_1), Higher education enrollment(C_2), College teacher-student ratio(C_3), Inbound mobility(C_4).

The fourth stage is product, including 5 Statistics, including Average years of education(D_1), World top 500 universities(D_2), Patent applications(D_3), Scientific publications(D_4) and Researchers in R&D(D_5).

On the basis of model building, we choose China and 16 countries for analysis, (Norway, Ireland, France, Finland, Denmark, Belgium, Switzerland, Sweden, Britain, Austria, Australia, Singapore, New Zealand, Israel, Canada, Netherlands), these nations have representative balanced and excellent higher education systems, most of which benefit from the solid foundation of basic education, economy, society, culture and history.

Step1: All indicators of the selected countries are taken as the basic panel data. The number of nations n = 17, the number of indicators m = 18, and a_{ij} is used to represent the j indicator of sample ($i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$), constitute the matrix as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nm} \end{bmatrix}_{n\times m} \tag{1}$$

Step2: Suppose the final higher education system score i is S_i. For the same index j, the corresponding indexes of the two nations are a_{ij} and $a_{ij}^{'}$ $(a_{ij} \neq a_{ij}^{'})$, and the final estimated scoring assumptions are respectively S_i, $S_i^{'}$ We set the following indicators:

$$\Delta K_j = \frac{S_i^{'} - S_i}{a_{ij}^{'} - a_{ij}} \tag{2}$$

Step3: We define the following positive data a_{ij}^{+} and negative data a_{ij}^{-}, which respectively represent data indicating positive and negative effects on national higher education system scores:

$$a_{ij} = \begin{cases} a_{ij}^{+}, \Delta K_j > 0 \\ a_{ij}^{-}, \Delta K_j < 0 \end{cases} \tag{3}$$

Step4: The extreme value method was used to standardize the data to reduce the influence of the relative size of each index on the calculation. Based on the principle of minimizing the influence on the internal laws of the data, all the dimensionless indicators are shifted to the right by a minimum of one unit (0.0001) to meet the requirements of calculations. Therefore, the results of initial data processing are as follows:

$$a_{ij}^{+} = \frac{a_{ij} - \min\{a_{1j}, \ldots, a_{nj}\}}{\max\{a_{1j}, \ldots, a_{nj}\} - \min\{a_{1j}, \ldots, a_{nj}\}} + 0.0001 \tag{4}$$

$$a_{ij}^{-} = \frac{\max\{a_{1j}, \ldots, a_{nj}\} - a_{ij}}{\max\{a_{1j}, \ldots, a_{nj}\} - \min\{a_{1j}, \ldots, a_{nj}\}} + 0.0001 \tag{5}$$

Step5: In order to simplify the calculation, we replace a_{ij}^{+} and a_{ij}^{-} with a_{ij} after normalization. Then we calculate the proportion of the sample i value under the index j to the total index.

$$p_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, i = 1, 2, \ldots, n; j = 1, 2, \ldots, m \tag{6}$$

Define the variable k, its size is related to the number of samples.

$$k = \frac{1}{\ln(n)}, 0 < e_j 1 \tag{7}$$

Step6: Calculate the entropy value e_j of the index j.

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}), j = 1, 2, \ldots, m \tag{8}$$

Step7: Calculate the entropy redundancy d_j of the index j.

$$d_j = 1 - e_j, j = 1, 2, \ldots, m \tag{9}$$

This index is inversely proportional to the entropy value. Therefore, the influence coefficient of the index j calculated according to the entropy weight method on p_i is w_j.

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{10}$$

The weight of the index is proportional to its impact on the education system. According to the entropy method, all the indicators of the selected 17 nations are summarized, and the weight w_j is calculated. The relationship between the score vector S_i, the data matrix A and the weight vector W is as follows:

$$S = AW = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nm} \end{bmatrix} \begin{bmatrix} w_1 \\ \vdots \\ w_m \end{bmatrix} \tag{11}$$

The Table 1 shows the weights and scores for higher education systems.

According to the research ranking of this cluster, China has the lowest performance, which has a great space for progress, the scale of education, the value of research and representativeness of policy recommendations.

Table 1. w_j corresponding to each indicator

Index j	w_j	Index j	w_j
A_1	0.1180	C_1	0.0163
A_2	0.0041	C_2	0.0116
A_3	0.0462	C_3	0.0231
A_4	0.0183	C_4	0.0591
A_5	0.0288	D_1	0.0181
B_1	0.0412	D_2	0.1805
B_2	0.1883	D_3	0.1140
B_3	0.0242	D_4	0.0482
B_4	0.0163	D_5	0.0361

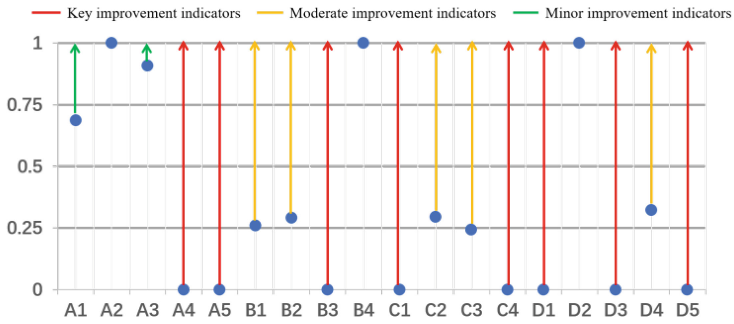

Fig. 1. China ranks in the same category

4 Quantitative Analysis of Current System Health Status

We analyze China's current higher education system and found that China still has large deficiencies in some index data.

China's level of higher education development is relatively weak at present, and its development space is huge. Considering the twists and turns of the system reform, especially the higher education reform, we propose a four-stage progressive ladder strategy and set up a relevant reform timeline according to the gap between the current state and the frontier nations and the 1/4, 1/2 and 3/4 points. As shown in the Fig. 1, there is a big gap between the red key improvement and the frontier nations, which requires continuous and gradual improvement in the fourth stage to steadily achieve the expected reform effect.

5 Policy Recommendations and Expected Implementation Process

In response to the current situation in China, we formulate the following policy system, and divide it into four stages, which can help China achieve the improvement of indicator data. First, sort the nations according to their scores, find the 1/4, 1/2, and 3/4 quantiles of each indicator, and determine the location of the sample nation. Based on the gap between the current state and reform expectations, and the difficulty of actual improvement of the indicators, we divide it into key improvement, moderate improvement, and minor improvement. Among them, the development process of key improvement indicators has a long gap and needs to be gradually improved in four stages. Moderate improvement can be improved in 2–3 stages. Minor improvement means that the nation is in a better state and the gap is smaller, and it can catch up with the frontier nations faster. (As shown in Table 2).

Table 2. Process of Policy Implementation

		Policy Proposal	Stage1	Stage 2	Stage 3	Stage 4
context	A1	Control population aging Maintain a population of the right age for higher education	71.20	71.20	71.20	71.20
	A2	Stabilizing prices (e.g. CPI)	121.56	121.56	121.56	121.56
	A3	Fully implement nine-year compulsory education Pilot expansion of compulsory education in some areas	101.21	104.12	104.12	104.12
	A4	Increase GDP per capita Persist in poverty alleviation	9976.68	9976.68	9976.68	9976.68
	A5	Improve government governance capabilities (E.g. continue to insist on anti-corruption)	42.61	42.61	42.61	42.61
input	B1	Increase total investment in education	1.73	2.09	2.45	2.45
	B2	Increase research funding support Optimize and standardize scientific research funding management	2.95	3.63	4.30	4.30
	B3	Increase the proportion of college education funds	14210.20	22491.99	30773.78	39055.58

(*continued*)

Table 2. (*continued*)

		Policy Proposal	Stage1	Stage 2	Stage 3	Stage 4
	B4	Implement financial aid for college students Innovative funding forms and tools	55.49	55.49	55.49	55.49
process	C1	Strengthen management during higher education	41.57	49.48	57.40	65.31
	C2	Continue to adhere to the "lenient entry and strict exit" policy Expand the coverage of higher education channels	58.29	64.98	71.66	78.34
	C3	Expanding the faculty of higher education Vigorously train higher education teachers	14.26	11.14	8.01	4.89
	C4	Optimize the management of international students Enhance the international influence and reputation of universities	6.92	13.45	19.98	26.50
product	D1	Pilot projects to increase the length of compulsory education	10.25	11.47	12.70	13.92
	D2	Optimize institutional arrangements for universities	51.00	51.00	51.00	51.00

(*continued*)

Table 2. (*continued*)

		Policy Proposal	Stage1	Stage 2	Stage 3	Stage 4
	D3	Encourage the transformation of basic science to patented technology	91.26	168.06	244.85	321.65
	D4	Strictly control the quality of academic publications Enhance the international influence of academic publications	874.53	1081.76	1289.00	1289.00
	D5	Improve the salary of scientific researchers Conduct career guidance for college students	2996.81	4686.50	6376.20	8065.89
Expected score at each stage			0.2827	0.3574	0.4335	0.4916

6 Impact of Policy Implementation

The closer China's score to each indicator is to the highest value in the cluster, the more effective the policy implementation is. We assume that China's scores in the four parts are: S_A, S_B, S_C, S_D. In the cluster where China is located, we assume that the highest scores of the four parts are $S_{Amax}, S_{Bmax}, S_{Cmax}, S_{Dmax}$. In the process of policy optimization, the scores of the four parts are all satisfied:

$$S \rightarrow S_{max} \tag{12}$$

At the same time, we set the following variable:

$$\Delta S = \frac{S_{max} - S}{S_{max}} \tag{13}$$

The size of ΔS reflects the room for improvement in China's score. If ΔS = 0, it means that China's score has reached the highest value among countries in the same category.

The data calculated according to the above process is shown in Table 3, this data reflects the gap between China and the overall policy goals. From this, we can find that policy improvements will have different impacts on various parts of China's higher education system:

Table 3. The role of policies in various stages in improving scores

Stage	1	2	3	4
A	0.0404	0.0515	0.0512	0.0510
B	0.0739	0.0215	0.0219	0.0218
C	0.0427	0.0066	0.0067	0.0068
D	0.1256	0.0149	0.0150	0.0151

- **Context:** China's basic education indicators have advantages and there is little room for improvement. Moreover, basic indicators are related to comprehensive national strength, and it is difficult to achieve substantial changes in the short term. Therefore, our policies have not significantly improved the basic indicators of China's higher education system, such as GDP per capita and CPI.
- **Input:** In terms of input indicators, China still has a lot of room for growth. Therefore, our policy choice is to optimize and improve investment indicators in the first stage. It can be found that with the investment in higher education, the growth rate of investment indicators is gradually decreasing, and the gap with developed countries is gradually narrowing. This shows that our policy has significant effects and is conducive to China's higher education modernization.
- **Process:** In terms of process indicators, our policy emphasizes the expansion of higher education teachers while strictly controlling the graduation rate and other indicators. The Chinese government needs to start with quality to improve the health and sustainability of China's higher education system.
- **Product:** Output indicators are affected by the first three types of indicators and are the result of them. The policies we put forward are in line with the law of gradual advancement, so it can achieve a reasonable optimization and layout of China's higher education.

In summary, the policy system we have implemented has a positive impact on China's higher education system as a whole.

7 Resistance in Policy Implementing

In order to ensure the practicality and effectiveness of the policy, we decomposes the policy suggestions, and some of the development suggestions are divided into multiple stages for implementation. Such as: China A_4, A_5, B_3, C_1, C_4, D_1, D_3, D_5 indicators. The difficulties in the healthy and sustainable development of higher education system are summarized as follows:

- Higher education and scientific research, technological innovation, is closely related to international talent flow.
- The impact of culture is long lasting and subtle. The culture and education of a nation is directly related to its cultural origin and historical precipitation.

- There are prerequisites for the development of higher education, such as social security, national elementary education, teaching and scientific research infrastructure, the international talent to the free flow and so on.
- Nowadays, the gap of national higher education system is very remarkable. In general, as shown in the model, the disparity in the development of higher education in the example nation of China is remarkable, and the improvement in many aspects has some difficulties.

8 Conclusion

Taking China for example, we propose four stages of higher education development and evaluate the policy impact based on the conclusions of this paper. This article's usefulness is in providing specific guidelines for China's future high education policymaking, and other nations with comparable national circumstances can utilise it as a guide. Future research must concentrate on significant modifications to the countries' educational systems in order to modify the model.

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