ISSN: 2688-8653

Higher Education System Evaluation based on Fuzzy Comprehensive Assessment Model

Runxin Wang

School of economics, Beijing Technology and Business University, China

1694946653@qq.com

Abstract

Higher education can be compared to the brain of a nation, which is the intellectual support for the continuous development of the country. Most previous studies have only measured the health of a country's education system from a single indicator, failing to take most other factors into account. In addition, most studies only conducted qualitative studies on educational indicators, so there is a lack of quantitative assessment of the health of national education systems. In such a research background, we extract useful information from the previous research, but more importantly, we've made a combination of international data, computer algorithms and mathematical models. In order to measure and assess the health of a system of higher education at a national level and for international comparability purposes, we apply Fuzzy Comprehensive Evaluation (FCA) method for quantitative processing. To solve the problem that the determination of the weight of each indicator needs the knowledge and experience of experts, we use the Analytic Hierarchy Process (AHP) to determine the weight of each indicator. As for the problem of needing experts to evaluate each indicator in AHP again, we innovated by using the Interval Scoring Method created by our own to evaluate each indicator.Based on this model, we can generate a comprehensive index of the world average level and of each country. We selected the U.S, China and Nigeria, which respectively belong to developed countries, developing countries and less developed countries, to demonstrate our model's robustness. On top of that, we've made a case analysis of China by employing a linear regression forecasting model to predict the likelihood and time required to migrate its current state to our proposed state for China. We put forward some reasonable policy advice and also discuss several difficulties that it might encounter.

Keywords

Higher Education ; Fuzzy Comprehensive Assessment; Analytic Hierarchy Process.

1. Introduction

1.1. Literature Review

Over the past few decades, higher education has witnessed tremendous growth around the world — increased participation, favorable policy environment, higher research level and so on. However, due to lack of comparative data and measurements that are difficult to define, how to quantify the level of a country's higher education system has always been a difficult problem.

Having done a lot of research and reading, we find that the previous research has not answered this problem satisfactorily. Most previous studies have only considered individual aspects of higher education, instead of taking into account different factors to make a comprehensive assessment. Since education is constantly evolving, especially in the case of the current pandemic, the existing research is in need of being updated.

In this paper, we have conducted a model which can fulfill the gap in the literature. First, by summarizing previous studies, we have concluded 5 different indicators that can be used to evaluate the higher education system. These indicators have a relatively weak correlation, thus can be used to measure the performance of a country's higher education in different aspects, helping to provide a comprehensive analysis of whether an education system is healthy and sustainable. After that, we collected a lot of raw data on higher education from official data sites to make sure the data are reliable. After filtering and processing the data, we use Interval Score Method introduced by ourselves to make an assessment of how the world as a whole is generally doing in each indicator. We then use the Analytic Hierarchy Process to assign weights to each indicator, allocating their respective weight in our assessment of the education system. Thereafter, we apply the Fuzzy Comprehensive Assessment model to generate a value that can reflect the higher education level of a country.

It is not enough to just have an academic comprehensive indicator, we need to apply it in making a realistic assessment. In order to test the rationality and feasibility of our model, we selected three countries belonging to different stages of development for calculation, and compared the results of the three countries. Among them, we choose China for further analysis, find out the aspects that it still has room for improvement. Based on the linear regression model, we predict its development trend and puts forward some policy suggestions. Of course, we also anticipate some obstacles and difficulties that may be encountered during the transition period of policy implementation.

Here’s an overview of our work:

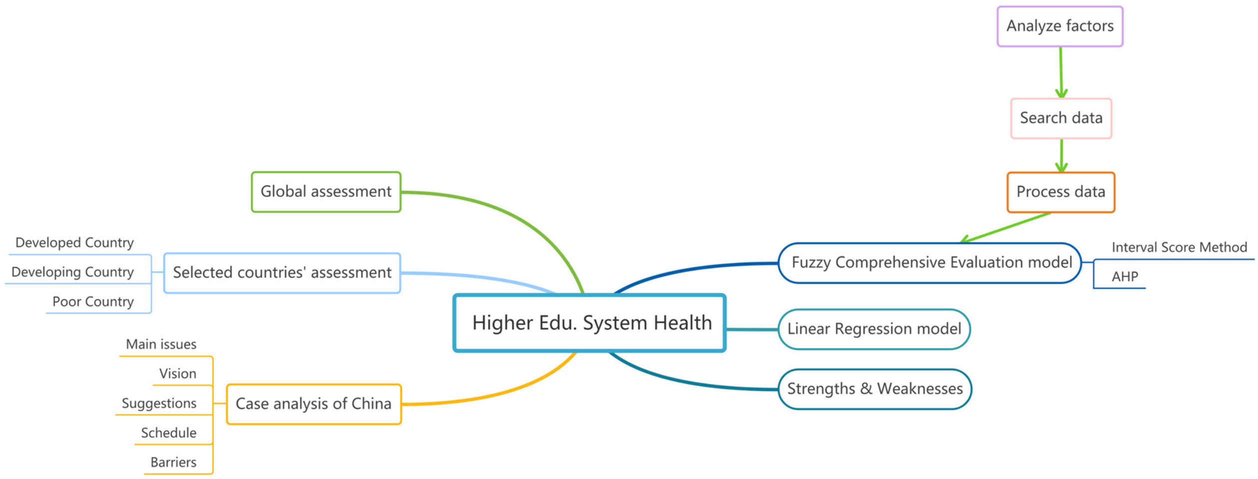

Fig 1. Overview of our work

The paper will be helpful for the authorities, students, parents and academic institutes to analyze and assess the performance of a country’s higher education system.

1.2. Problem Clarification

How can we measure and assess a country’s higher education system? How to test whether the country's higher education system is healthy and sustainable? To answer this question, we need to develop a quantitative assessment mechanisms that can be used to calculate a comprehensive health index of a country's higher education system. If the quantitative method is unscientific, then the reliability of the evaluation results will be poor. Specifically, we need to meet the following requirements

·Determine what kind of higher education can be considered healthy and sustainable, that is, what criteria a country's higher education system needs to meet in our model.

ISSN: 2688-8653

·Apply our model to several selected countries' higher education systems to demonstrate the model results.

·Select one of the countries for further analysis according to its scores in various aspects, and put forward some policy advice to improve its deficiencies (if there is any) and explain the reasons.

·Discusses the practical (as opposed to the academic) impact and possible difficulties encountered in the process of improving the higher education system and implementing policies on various walks of society.

It is our hope that a wide range of stakeholders — policymakers, research institutions, foundations etc. — can use our model to assess a country's higher education system. Furthermore, we hope that the insights it brings can lead to substantial improvement of our higher education system.

2. Assumptions

In this document, all analysis, reasoning and conclusions are based on the following assumptions:

·Assumption 1: All the factors are independent and interactions between the factors are not taken into account. In reality, these indicators inevitably influence each other, but in order to simplify the model, we choose to ignore the interaction between these factors.

·Assumption 2: In the analytic hierarchy process (AHP), we assume that the importance relationship between the indicators is: accessibility >= education equity >= educational attainment > Government expenses > research level; School enrolment ratio > pupil-teacher ratio; papers = patents; Doctoral >= Master's >= Bachelor's >= short-cycle; % of GDP >= staff compensation; Gender = location = wealth. The specific reasons for this will be given in a later analysis.

·Assumption 3: All the data are true and valid. We've collected the data we needed to evaluate the weight of each indicator from various official data sites (World Bank, UNESCO etc.) to ensure the data was reliable. Data sources will be given in the references.

3. Analysis of the Problem

3.1. Define the Concepts

A healthy and sustainable higher education system

We believe that a healthy and sustainable higher education system is one in which the whole society has high levels of access, equity, education, government support and research.[1]

Higher Education

In this paper, higher education includes short-cycle tertiary education, bachelor's or equivalent level, master's or equivalent level and doctoral or equivalent level.[2]

Accessibility[3]

The ability of people from all backgrounds to access higher education.

Education Equity

Any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications.

Educational Attainment

The highest degree of education an individual has completed.

Government Expenditure

ISSN: 2688-8653

Government spending on higher education.

Level of Research

A measure of achievement, fairness, and opportunity in education.

3.2. Methodology

Since we are to both assess different aspects of a country's higher education system and make intuitive international comparisons, a model that is suitable for jointly evaluating multi-agent and multi-category indicator information is needed. The difficulty of this problem lies in the selection of evaluation indicators and the problem of quantitative process, especially the latter. For such a problem that contains a lot of fuzzy phenomena and fuzzy concepts, we choose fuzzy comprehensive assessment model, which has both qualitative and quantitative indicators, to transform qualitative problems into quantitative ones, so that it can better solve the problems that are difficult to quantify.

The Fuzzy Comprehensive Evaluation Model is based on indicators, grades and weights. For each variable, we use different methods to determine it. For indicators, we summarized previous literature to determine various parameters and criteria for assessment. For grades, we used Interval Score Method which is designed by ourselves to evaluate each indicator's grade. For weights, we applied Analytic Hierarchy Process to confirm each indicator's weight.

This paper is divided into four parts following an introduction: analysis of the problem, model design, exhibition of the results, validating the model, and conclusions. The end of the report also includes individual country reports which profile national education system assessment results, and two appendices relating to data and the code of the computer algorithm that we have used.

3.3. The Processing of Data

The data used in this paper includes data on higher education as reported by World Bank and UNESCO, spanning from 2017 to 2019. Details on our processing of the data used are as follows:

Specifically, we collected the data on school enrollment ratio, student-faculty ratio, educational attainment, education equity (including gender equity, location equity and wealth equity), government expenditure, papers and patents. The first three were collected from the World Bank website, the middle two were collected from the UNESCO website, and the last two were collected from the WIPO website.

·For student-teacher ratio, It is inversely proportional to the level of the higher education system, whereas other numerical indicators (such as enrolment, number of papers, etc.) are in direct proportion. In order to facilitate the application of data in the model, we take its reciprocal for research, namely faculty-student ratio, making it proportional to the level of higher education system.

·Since the data of some years are not available on the website (due to political turmoil, natural disasters and other overwhelming reasons), so we have to choose similar years to fill in, but the selected years are all between 2017 and 2019, in order to avoid large deviation. If a country has no data in between, we exclude that country from our assessment.

3.4. Notations

We will use the nomenclature in Table 1 in this paper. Other symbols that are not frequently used will be introduced once they show up.

Table 1. Notations

Symbol	Definition
Q	Interval length
Max	The maximum number in a set of data

ISSN: 2688-8653

Min	The minimum number in a set of data
α_{ij}	Membership function
β_{ij}	Grades of each parameter
W_{ij}	The weight associated with each indicator
$\circ$	Fuzzy synthesis operator
E_0	The proportion of the overall level of higher education in each grade range
R	Fuzzy matrix
F	Final score

4. Model Design

4.1. Determine the Indicators

There are a wide range of factors affecting higher education, from which we need to select several representative indicators. Our indicators are not chosen randomly, but rather, we have pooled a large body of previous research to select a few widely accepted indicators.

Higher education studies, which have already attempted to determine these factors will be the basis of our selecting the indicators. Our comprehending of the literature on higher education permits us to conclude the following proposed indicators, which are easy to understand and widely accepted in real life:

Table 2. Indicators

Primary Indicator	Secondary Indicator
Accessibility[4]	School Enrolment
	Faculty-student ratio
Education Equity	Gender
	Location
	Wealth
Educational Attainment	Short-Cycle
	Bachelor's Master's
	Doctoral
Government Expenditure	% of GDP
	Staff Compensation
Level of Research	Papers
	Patents

As is seen from the above, we've determined accessibility, education equity, educational attainment, government spending and level of research as our basic indicators for measuring the education system, under which we determine several sub-indicators to make our model results more precise. According to our assumptions, the importance of the primary indicators is in descending order.

The level of educational attainment people have attained is measured according to the International Standard Classification of Education (ISCED).

4.2. Interval Score Method

In the traditional AHP which we will use in the latter section, different experts are needed to score the same indicator, and the result is calculated according to the proportion of experts' evaluation in each segment. No losing of its universality, we have innovated in this regard. Since there is no such activity in the world to organize a number of experts to score the national education system, our group can only determine the health of each country according to its ranking of each indicator in the range of the world. We divide the world rankings into 5 different grades, from high to low corresponding to the assessment level of high, medium high, medium, medium low and low respectively, and each ranking interval is correspondingly given a score interval, which is more intuitive in the following two tables (Table 3 and Table 4). From the macro level of the world, the proportion of the number of countries in a certain range is the proportion of the indicator's evaluation under that range. We name this method Interval Score Method. See the flowchart below to have a better understanding of this process:

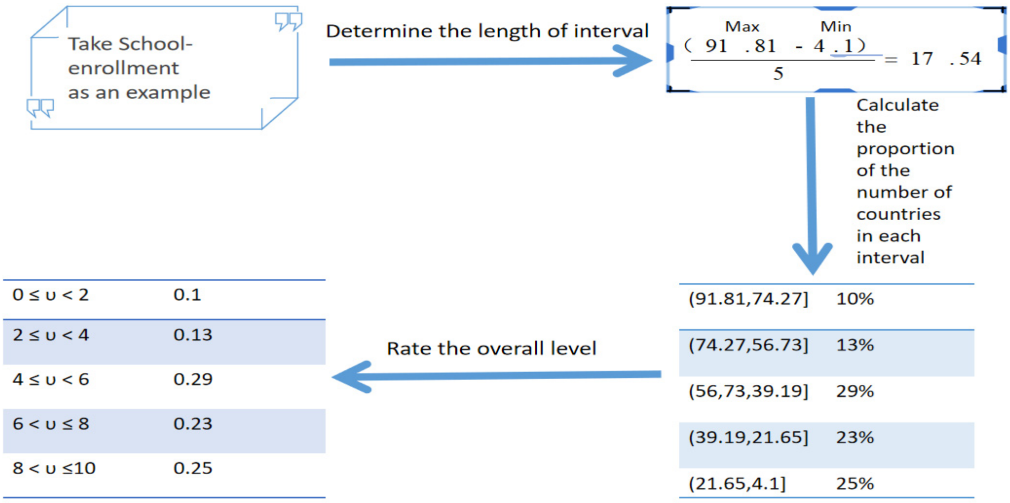

Fig 2. Flowchart

According to different measurement standards of the data, we divided the indicators into numerical type and proportional type, and used Interval Score Method to evaluate them respectively. (See the appendix for specific calculation methods of secondary indicators).

Numerical indicators include school enrolment ratio, faculty-student ratio, papers, patents, degrees, % of GDP and staff compensation. The level of these indicators is in proportion to the health of the system. We first sorted the global data, and then divided them into five levels using the formula below to get the length of each interval

$$Q = \frac{(Max - Min)}{5}$$

Next, we calculate the proportion of the number of countries in different intervals, which we will use in the AHP to assess how the world as a whole is doing on various indicators.

Proportional indicators include gender equity, location equity and wealth equity indicators, and the result is between 0 and 2. The closer it is to 1, the fairer it is. Therefore, we take 1 as the full mark standard and divide the data into 5 categories, namely.

Table 3. The grade corresponding to the range in which the country is ranked

Ranking range	80%-100%	60%-80%	40%-60%	20%-40%	top 20%
Grades	low	Medium low	Medium	Medium high	High
Scores	$0 \le \upsilon < 2$	$2 \le \upsilon < 4$	$4 \le \upsilon < 6$	$6 < \upsilon \le 8$	$8 < \upsilon \le 10$

Table 4. The grade corresponding to the interval in to which the country belongs

Value Interval to which it belongs	**Grades**	**Scores**
$(\mathbf{0-0.2}] \cup (\mathbf{1.8-2.0})$	Low	$0 \le \upsilon < 2$
$(\mathbf{0.2-0.4}] \cup (\mathbf{1.6-1.8}]$	Medium low	$2 \le \upsilon < 4$
$(\mathbf{0.4-0.6}] \cup (\mathbf{1.4-1.6}]$	Medium	$4 \le \upsilon < 6$
$(\mathbf{0.6-0.8}] \cup (\mathbf{1.2-1.4}]$	Medium high	$6 < \upsilon \le 8$
$(\mathbf{0.8-1.0}] \cup (\mathbf{1.0-1.2}]$	High	$8 < \upsilon \le 10$

Then we have the number and proportion of countries in each range of rankings. After that, we can rank and score the countries to get the evaluation of each indicator. The results computed by Interval Score Method will be used in the following indicator weighting model.

4.3. Indicator Weighting Model

Analytic Hierarchy Process

An appropriate allocation of weight to each indicator is crucial to FCA. The determination of reasonable weight can influence the outcome of the assessment. Since the impact and importance of each indicator on the education system is not equal, we cannot simply assume that every indicator has the same importance, for that would lead to a huge deviation from reality. To get a comprehensive index of a country's education system, we need to give individual weights to each indicator.

Besides, the FCA model requires the determination of the weight of each indicator scored by experts, which is impossible to achieve in our paper and has a certain degree of subjectivity. Therefore, in this case, we use Analytic Hierarchy Process (AHP) to determine the weight of each indicator. AHP is one of Multi Criteria decision making method to derive ratio scales from paired comparisons.[5] The input can be some actual measurement such as weight, height etc., or some subjective judgement. Since it is difficult to set an objective and universal standard for subjective preference, the AHP approach does not necessarily involve experts to take part in the evaluation, therefore it is a suitable and logical approach for us to compute the weight of each indicator.

In the following sections we will detail the mathematical method of using AHP to determine weights. The computer algorithm program of AHP will be shown in the Appendix section.

Pair-wise Matrix

We need to do a pairwise comparison for every two indicators. And for each comparison, we need to make a relative scale to measure which one has higher importance and to what degree. This process can be simplified to the following table:

Among the primary indicators, since we have 5 of them, we'll get 10 comparisons. As mentioned before, we assume that the importance of primary indicators can be intuitively expressed as:

ISSN: 2688-8653

accessibility >= education equity >= educational attainment > Government expenses > research level.

Table 5. The example scale for comparison (Saaty & Vargas, 1991)

Degree of preference (*Indicator i* over *indicator j*)	Preference values	Symbol in this paper
Equal importance	1	=
Moderate importance of one factor over another	3	>
Strong or essential importance	5	>>
Very strong importance	7	>>>
Extreme importance	9	>>>>
Values for inverse comparison	2, 4, 6, 8	>=,>>=,>>>=,>>>>=

With each group comparison, we can get a pairwise comparison matrix. For example, comparing accessibility and education equity, the former is slightly more important than the latter, thus we put 2 in row 1 column 2 of the matrix. Comparing education equity and research level, the former is more important than the latter, thus we put 4 on the second raw, last column of the matrix. Then based on preference values above, we can have a 5 by 5 comparison reciprocal matrix in

$$A = \begin{pmatrix} 1 & 2 & 3 & 5 & 6 \\ & 1 & 2 & 3 & 4 \\ & & 1 & 2 & 3 \\ & & & 1 & 2 \\ & & & & 1 \end{pmatrix}$$

To fill the lower triangular matrix and also to meet the consistency requirements, we use the reciprocal values of the upper diagonal. Namely, if $a_{ij}$is the element of row i column j of the matrix, then the lower is filled using the formula

$$a_{ji} = \frac{1}{a_{ij}}$$

Thus now we have complete comparison matrix

$$A = \begin{pmatrix} 1 & 2 & 3 & 5 & 6 \\ 0.5 & 1 & 2 & 3 & 4 \\ 0.33 & 0.5 & 1 & 2 & 3 \\ 0.2 & 0.3 & 0.5 & 1 & 2 \\ 0.16 & 0.25 & 0.33 & 0.5 & 1 \end{pmatrix}$$

And the rest can be deduce in the same manner, according to our assumptions of the order of importance, the matrices of the five primary indicators' secondary indicator are respectively

$$A_1 = \begin{pmatrix} 1 & 7 \\ 0.14 & 1 \end{pmatrix}; A_2 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}; A_3 = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{pmatrix}; A_4 = \begin{pmatrix} 1 & 3 \\ 0.33 & 1 \end{pmatrix}; A_5 = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$$

Priority Vector[6]

Now that we have the pairwise comparison matrix, we can compute the Priority Vector, also called Eigen Vector. This step is to normalize the matrix by totaling the numbers in each column. Each entry in the column is then divided by the column sum to yield its normalized score.

Sum the values in each column of the pair-wise matrix

ISSN: 2688-8653

$$A_{ij} = \sum_{i=1}^{n} a_{ij}$$

Divide each element in the matrix by the sum of its column total to generate a normalized pair-wise matrix

$$X_{ij} = \frac{A_{ij}}{\sum_{i=1}^{n} A_{ij}} = \begin{pmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nn} \end{pmatrix}$$

Divide the sum of the normalized column of matrix by the number of criteria used (n) to generate weighted matrix, namely priority vector that we need

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} = \begin{pmatrix} W_{11} \\ \vdots \\ W_{n1} \end{pmatrix} = (W_{11} \quad \cdots \quad W_{1n})^{T}$$

It is noted that

$$\sum_{j=1}^{m} W_{1j} = 1$$

We mark the weight matrix of primary indicators as W and the weight matrices of each group of secondary indicators that is subordinate to the same primary indicator as $W_i (i = 1,2,\cdots,5)$. Based on the above formula, we can generate the Priority Vector for the group of primary indictors and each group of secondary indicators:

$$W = (0.44 \quad 0.25 \quad 0.16 \quad 0.09 \quad 0.06)$$

$$W_1 = (0.87 \quad 0.13)$$

$$W_2 = (0.33 \quad 0.33 \quad 0.33)$$

$$W_3 = (0.46 \quad 0.28 \quad 0.16 \quad 0.1)$$

$$W_4 = (0.75 \quad 0.25)$$

$$W_5 = (0.5 \quad 0.5)$$

The infinite decimal in the calculation process is treated with two decimal digits reserved, which may cause slight deviation, but due to the fuzziness of the evaluation of the education system, the error can be basically ignored. With the Priority Vector, we can use it in the FCA model.

4.4. Fuzzy Comprehensive Assessment Model

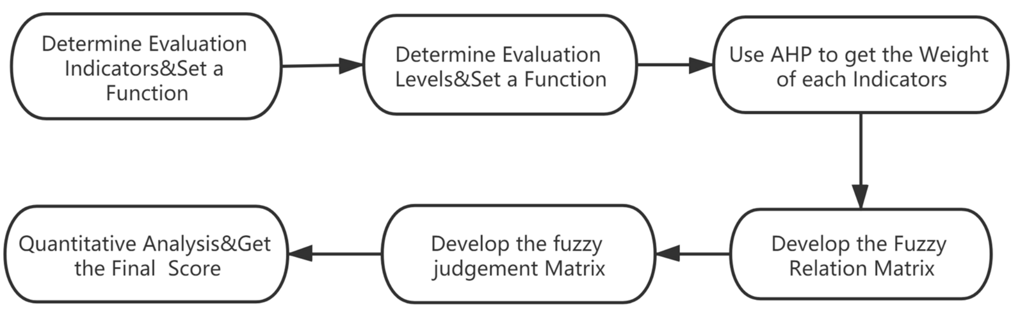

Fig 3. Procedure

ISSN: 2688-8653

On account of numerous and complicated factors affecting the education level which are not suitable for quantitative study, we set up a Fuzzy Comprehensive Assessment model of higher education to comprehensively evaluate the education level of the world at the present stage.

To intuitively illustrate how FCA works, we outlined the procedure as shown in Fig 3.

Mathematically, the indicators could be assigned a set of function:

$$\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_n)$$

where $\alpha_1, \alpha_2, \cdots, \alpha_n$ are the indicators (e.g. accessibility) assessed for the study and n is the total number of these indicators. Besides, grades for each indicator are established based on Interval Score Method (See *Table 3* and *Table 4*). The grades can be defined using the set function:

$$\beta = (\beta_1, \beta_2, \cdots, \beta_5)$$

where $\beta_1, \beta_2, \cdots, \beta_5$ respectively stands for low, medium low, medium, medium high and high.

In the previous section, we have used the AHP to get the weight matrix $W_i (i = 1,2,\cdots,5)$.

$$W = \left({W_1}^T, {W_2}^T, \cdots, {W_5}^T\right)^T$$

Carrying out single-factor evaluation of secondary indicators subordinate to each primary indicator, we use the Interval Score Method to generate 5 fuzzy relation matrices $R_1, R_2, \cdots, R_5$

The assemblage of each indicator and its weight can be arrange into a fuzzy matrix $R_i (i = 1,2,\cdots,5)$

$$R = \begin{pmatrix} \alpha_{11} & \cdots & \alpha_{1n} \\ \vdots & \ddots & \vdots \\ \alpha_{51} & \cdots & \alpha_{5n} \end{pmatrix}$$

Through respective fuzzy transition of R and W, we have the fuzzy judgement set E of each primary indicator:

$$E = W \circ R = \begin{pmatrix} E_1 \\ E_2 \\ \vdots \\ E_5 \end{pmatrix}$$

This model involves simple fuzzy classification where the matrices obtained from fuzzy membership functions are subjected to weighted average method of fuzzy reasoning.[7]

And then we have E_0 that stands for the proportion of the overall level of higher education in each grade range

$$E_0 = E \circ W$$

Since we apply the interval to grade each indicator, it is difficult to compute the result. To simplify this process, we define S as the average of each score interval

$$S = (1, 3, 5, 7, 9)$$

Next we can determine the score interval for each primary indicator according to the maximum membership principle, and finally we get the final score F of the Fuzzy Comprehensive Assessment model

$$F = E_0 S^T$$

This formula can not only strongly reflect the weight, but also reflect the information of the grade, with a strong degree of synthesis.

ISSN: 2688-8653

5. Exhibition of the Model Results

Looking at the results for the world as a whole and individual countries, we found both bright spots as well as sobering outcomes worthy of further exploration.

First we want to show how countries around the world are doing in terms of gender equity. We collected The Adjusted Gender Parity Index (GPIA) data from The World Bank and made a coloring map of the world to make it more visual. The GPIA is calculated by dividing the female value for the indicator by the male value for the indicator. If the resulting value exceeds 1, the ratio is inverted and subtracted from 2. The adjusted gender parity index is symmetrical around 1 and lies in the range 0-2. An adjusted GPI equal to 1 indicates parity between females and males. In general, a value less than 1 indicates disparity in favor of males and a value greater than 1 indicates disparity in favor of females.[8]

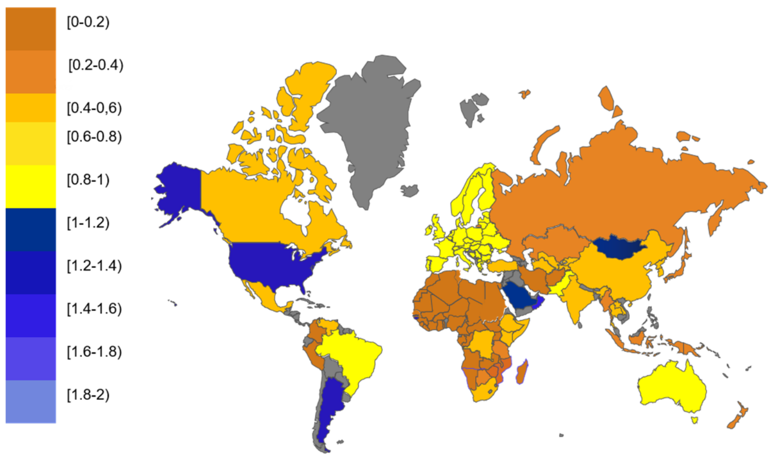

Fig 4. Color map of the world

From the map above, we can see that the world's higher education is still generally skewed towards male, but mostly within a reasonable range. Extreme gender inequality is rare but still exists, mostly in less developed countries, worst in Africa.

It is easy to notice that the equity of a country's higher education has a lot to do with its level of development. Intuitively, the more developed a country is, the fairer its higher education system is. Inspired by this, we decided to select three countries with different levels of development — the United States, China and Nigeria — to test the model, wondering whether it will give us a reasonable result.

5.1. World

In order to better compare the health and sustainability of each country’s higher education system, we use the model to evaluate the average level of the world in the first place. The results are as follows:

Fuzzy judgment set

$$E_0 = (0.21, 0.26, 0.33, 0.13, 0.07)$$

From the above we can see that its overall score is in the range of 4 to 6, hence it generates its final score

$$F = 4.19$$

5.2. The United States

The education system in the United States is considered to be relatively developed and advanced, and therefore is expected to have high levels of health and sustainability. However,

ISSN: 2688-8653

as we calculate its score, we find that it is not as high as we thought it would be. The results are shown as follows:

$$E_0 = (0.01, 0.10, 0.46, 0.18, 0.25)$$

$$F = 6.11$$

It's not that our model doesn't match reality. Rather, it's that our model has identified significant problems in the U.S. higher education system. After further retrospecting the reasons, we identify the indicator that leads to this result — education equity, which fuzzy judgment set is

$$E_2 = (0.01, 0.51, 0.2, 0.17, 0.01)$$

As we can see, it only scores between 2 and 4 on the indicator of educational equality. It is much lower than the United States' scores on other indicators. In addition, since our model gives high weight to educational equity, its low score in this indicator makes its final score not as high as expected.

This is also very much in line with reality. Due to the historical racial discrimination and the unequal distribution of social wealth, inequality is a noticeable problem in the U.S society and its higher education system does have a huge gap in fairness. This proves the robustness and accuracy of our model again.

5.3. China

China is a developing country and its score can represent the level of other developing countries in the world to a large extent. China's fuzzy judgment set is

$$E_0 = (0, 0.06, 0.56, 0.34, 0.04)$$

So it tells that the overall score is in the range of 4 to 6, and its final score generated is

$$F = 5.56$$

In the following case study, we will carry out a detailed analysis of various indicators of China, so we will not go into details here.

5.4. Nigeria

Nigeria is a typical representative country in Africa. Recently, it has been developing its economy and participating in international affairs vigorously. However, to develop a country's economy, higher education is a vital and integral part, thus the analysis of its higher education level is also of great significance to the development of a country. Nigeria's fuzzy judgment set is

$$E_0 = (0.69, 0.20, 0.11, 0, 0)$$

Its overall score is in the range of 0 to 2, and its final score is

$$F = 1.85$$

Nigeria's scores are much lower than the world average, reflecting serious deficiencies in its higher education system. We suggest policymakers and international organizations should take measures to improve the situation.

6. Case Analysis of China

It can be seen from the calculation results that the main problem in the education and health of the United States is education equality. Considering that it has been a long-term problem in the American society and the research on this problem has been quite mature, we did not choose it

ISSN: 2688-8653

for our study. While Nigeria's education health index is low and does have a lot of room for improvement, it is also difficult to make practical policy advice due to its national conditions.

As a comparison, China's comprehensive education and health index is above the medium level, but some indicators are lower than the world equilibrium level, which has a large room for development. Moreover, China's current development trend and national conditions favors improvement in these areas and implementation of policy. Therefore, we choose China as the object of analysis.

By comparing the assessment results of China with the world average level and developed countries that are generally considered to have a healthier and more sustainable education system, we find that China has some room for development in these four areas: staff welfare, student-teacher ratio, regional equality and wealth equality. The table below show the comparison on staff compensation and faculty-student ratio between China and other agencies.

Table 6. Comparison between China and other agencies

	China	World	Developed Countries
Staff compensation	57.6	53.3	61.1
Faculty-student ratio	0.07	0.06	0.14

And equality in education is a common problem in all countries around the world, including China. Countries around the world score low on this indicator.

Jointly considering the factors that limits the development of China's education system, including funding resources, huge population base, national quality etc., with reference to global level and countries that excel in these areas, we have set several numerical targets for China in each area. In addition, we use the linear regression model to predict the time required to realize theses targets. Also, we have developed a series of policies in the following sections to help China achieve its goal of creating a healthier and more sustainable higher education system.

Table 7. Current state, proposed state, and schedule

	Current State	Proposed State	Schedule
Staff Compensation	54	60	2029
Faculty-student ratio	15	10	2029
Location Equity	0.6	0.85	2046
Wealth Equity	0.35	0.6	2047

The data in the above table shows the time required for these four indicators to achieve the expected effect through linear regression model fitting. Among them, it takes nearly 10 years for teacher welfare and student-teacher ratio, while it takes nearly 30 years for regional equality and wealth equality to be realized.

We expect to establish a system where the comprehensive final score F reaches 6, the score of government expenditure increases from 4.7 to 6.7, educational accessibility increased from 5.2 to 5.5, the comprehensive index of education equity increased from 4.5 to 5.8, with the average level of all indicators in this system higher than the world average. This will optimize the health of higher education system and contribute to the sustainable development of higher education in China. (*Note:* The above estimated comprehensive evaluation indexes are calculated by substituting the expected indexes into the model.)

ISSN: 2688-8653

6.1. Regression Prediction Model

The following is the linear regression fitting diagram of the four indicators, the fitting equation $y = ax + b$, (a and b are arbitrary constants), and the fitting degree R^2.

Mathematically, using the Ordinary Least Square and Functional differentiation to calculate the regression equation coefficient can be expressed by the formula

$$\begin{cases} \sum y_i = na + b \sum x_i \\ \sum x_i y_i = a \sum x_i + b \sum {x_i}^2 \end{cases}$$

$$\begin{cases} b = \dfrac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} = \dfrac{n \sum x_i y_i - \sum x_i \sum y_i}{n \sum {x_i}^2 - (\sum x_i)^2} \\ a = \dfrac{\sum y_i}{n} - b \times \dfrac{\sum x_i}{n} = \bar{y} - b\bar{x} \end{cases}$$

and goodness of fit R^2 can be calculated by

$$R^2 = \frac{\sum \hat{y_i}^2}{\sum {y_i}^2}$$

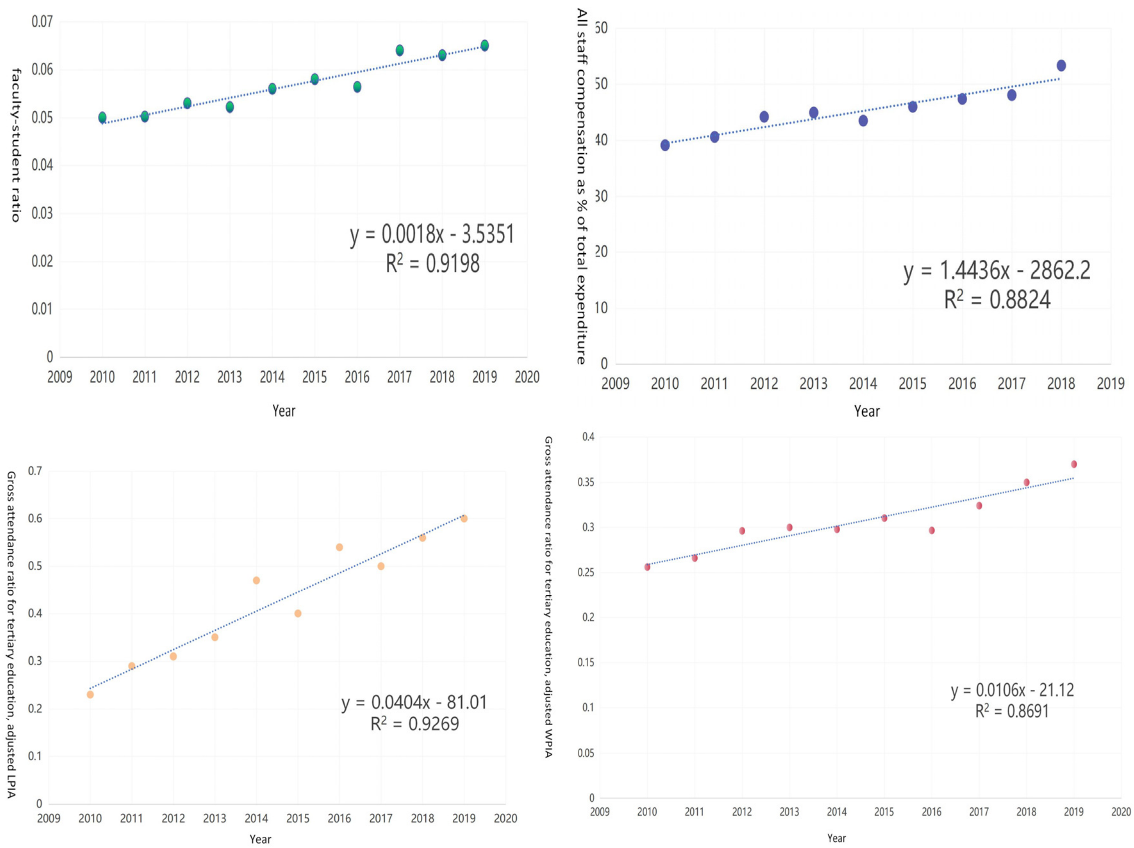

Fig 5. Goodness of Fit Test Plot

Then, the goodness-of-fit test is carried out to verify the feasibility of the model. The fitting degrees of the four indicators are all fairly good and have high-blooded forecasting accuracy.

ISSN: 2688-8653

6.2. Policy Proposal

The policymakers need to take into account as more stakeholders from all walks of as possible, including students, teachers, staff, employers, parents, government, etc. Specifically, different solutions are needed to solve different problems.

As for staff compensation and faculty-student ratio, the key is to make higher education more attractive, to get more talented people into it, and to make faculty members who are already in it to willing to stay. Appropriate amounts of government spending should be allocated to support staff working in university campuses, whether they are faculty members, members of research institutes, or other staff working in campuses. In this way, we can make higher education positions attractive, maintain the human resources in higher education, increase the faculty-student ratio and produce more excellent students to serve the society.

As for location and wealth equity, we can improve the resource distribution system for higher education by setting up the data collection platform mechanism focused on detecting the above four points that need to be improved, monitoring the dynamics and correct the deficiencies in the development process in a timely manner. To ensure that resources are distributed as equitably as possible and more people have opportunities. We need to allocate education funds to those students who are in poverty, assign the higher education resources and quotas for each province in proportion to population, not wealth.

6.3. Obstacles that Might be Encountered

Government spending on education is limited. China's current top priority is to develop its economy, and heavy investment in industrial engineering is bound to lead to a squeeze on education spending.

People's perceptions are different in different areas. For the elites in megacities, they are reluctant to share higher education resources equally with students in remote areas, whereas some people in remote areas ignore the importance of higher education or even voluntarily give up the opportunity of higher education.

Social resources are limited. With the improvement of comprehensive higher education level, talents receiving higher education may face a more brutal competitive environment.

Uncontrollable factors, such as an epidemic, a global economic crisis, etc. can not be predicted. When a crisis strikes, a country's higher education system can be severely affected, a fairly good example of this is the current Covid-19 pandemic. What other crises will we meet in the future? We'll never know.

7. Strengths and Weaknesses

7.1. Strengths

In the establishment of the model, we have not only used the existing model for reference, but also adapt the model to the requirements. We find commonness from existing models and adjust the original model according to the characteristics of the problem. In addition, we have made innovations on this basis and introduced our own method to determine the score interval, which not only breaks through the limitation of the original model requiring experts, but also avoids the subjectivity of scoring according to our own preferences.

In terms of the results of the model, it is basically consistent with the reality. It can reflect both the higher education system of each country and the overall level of the world. It can reflect both the overall health status of a country’s higher education system and the specific status of the country in various indicators, allowing for targeted policy adjustments. It can provide information for prospective students, current students, faculty and alumni who are the group that is closely related to higher education.

In terms of the structure of the article, we have made the hierarchy of the article very clear. Every section of our paper is generalized with concise terms and developed in a logical way to ensure readers to be able to follow our thoughts. Our paper has strong articulation and cohesion, with every part of the process interlinked.

7.2. Weaknesses

Our weakness is mainly on the data. The data is not complete on the official website so not all of the data we selected are in the same year. Besides, in some instances data on total public expenditure on education refers only to the Ministry of Education, excluding other ministries which may also spend a part of their budget on educational activities.

Apart from this, there is a certain subjectivity in the selection of our hypothesis and indicators. Although this is based on our reading and summarizing of a large number of previous literatures, we cannot rule out the possibility that our understanding is biased. But because we use fuzzy mathematics, the subjectivity can be reduced.

8. Conclusion

We have built a model that can be used to measure the health of a country's higher education system in a comprehensive way, which can reflect the information of index, grade and weight at the same time.

We have innovated the original expert scoring method and adopted the interval scoring method, which is introduced in detail in this paper.

According to the model, we have conducted sample analysis on several countries and presented the results of our model. The results are basically consistent with the expectation and reality, and can be explained by our model.

We have established regression forecasting models for China, analyzed its current situation, proposed feasible development targets, and offered some policy advice for its transition from the current state to the proposed state. Also we admitted the possible difficulties during this transition period.

References

[1] F. Atuahene and A. Owusu-Ansah, "A Descriptive Assessment of Higher Education Access, Participation, Equity, and Disparity in Ghana," SAGE Open, vol. 3, no. 3, p. 215824401349772, Sep. 2013, doi: 10.1177/2158244013497725.

[2] UNESCO Institute for Statistics, International standard classification of education: ISCED 2011. Montreal, Quebec: UNESCO Institute for Statistics, 2012.

[3] "Global Higher Education Rankings.pdf." .

[4] "Monitoring cross-country performance in equality of access and affordability of tertiary education – a review of options.pdf." .

[5] "AHP_Tutorial.pdf." .

[6] K. Bunruamkaew, "How to do AHP analysis in Excel," p. 21.

[7] "Zhong and Dai - 2007 - A Fuzzy Comprehensive Assessment Model for Reflect.pdf." .

[8] "Education Statistics | Education Equality." https:// datatopics. worldbank. org/ education/ wQueries/ qdhs (accessed Feb. 06, 2021).

[9] "School enrollment, primary (% gross) | Data." https:// data.worldbank. org/ indicator/ SE.PRM. ENRR? end=2020&start=1970&type=shaded&view=chart&year=2017 (accessed Feb. 05, 2021).

[10] "WIPO Intellectual Property Statistics Data Center." https:// www3. wipo.int/ ipstats/ IpsStats Result value (accessed Feb. 05, 2021).