Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
F		**2124893**

Checking the Pulse and Temperature of Higher Education

Summary

Many countries in the world are paying increasing attention to the health of the higher education system which is related to the level of national development. Therefore, we build models for the health and sustainability of the higher education system and evaluate the level of higher education in each country and give effective recommendations.

For Issue 1 and 2, we first collect ten important indexes that affect the evaluation of higher education systems in the United States, Canada, Switzerland, and China. They include, for example, the employment and unemployment rate of college students, and the proportion of the population with higher education. Then we conduct **Analytic Hierarchy Process** through the evaluation data of two experts and determine the hierarchical and weight relationship between the indexes. Finally, we calculate the final judgement result of each country through the **Fuzzy Comprehensive Evaluation** method. In 2019, the final judgement results of **the United States**, **Canada**, **Switzerland** and **China** are **0.7912**, **0.7703**, **0.7827**, and **0.7545**(see **Figure 6**).

For Issue 3 and 4, we take China, who has the lowest final judgement result obtained in Issue 1 and 2, as our research object. By analyzing the weights and scores of the indexes, we select the **proportion of the population in higher education(PPHE)** and the **research quality index(RQI)** as indexes that need improvement. We collect their historical data and conduct **Time Series Analysis**. Then we use the **Damped Trend Model** to make future predictions for them. We use the 2020 Swiss final judgement result as the threshold. When China's final judgement result reaches **0.784237** which exceeds the threshold, we select the **PPHE 42.56%** and **RQI 61.72** for the year as the result and regard them as the vision for China's higher education system.

For Issue 5, we analyze the **PPHE** and **RQI**. Through the analysis of China's national conditions, we decide to focus on **adult higher education**. We first predict the number of people that the new policy need to promote. Then we assess the strength of higher education of provinces in mainland China through the **Analytic Hierarchy Process** and get the number of people need to increase in each province. In the end, we analyze the 10-year policy arrangements for each province. We propose that universities divide the subjects into **practical-based** and **research-based** subjects. The classification of subjects not only makes application-oriented students more competitive after graduation, but also makes research-oriented students more capable of research.

For Issue 6 and 7, we use the model in Issue 2 to evaluate the theoretical results of the new policy and get the final judgement result of China's higher education system in the next ten years. The new policy brings the final judgement result to **0.8030** in 2030, which is greater than the one without the new policy and the effect is very significant. Finally, we discuss the impact and difficulties during policy implementation from two aspects: **ownership of management rights** and **impact of market economy**.

Keywords: Hierarchical Analysis, Fuzzy Comprehensive Evaluation, Time Series Analysis

Contents

1 Introduction and Preparation

1.1 Background

The higher education system of a country is the key to training high-quality citizens in the country. Therefore, a country has a healthy and sustainable higher education system, which means that the country has a higher degree value, education quality and research level. This also indirectly indicates that this country has a high level of technological development. Each country has a different higher education system, which attracts students from different countries and regions around the world to study abroad. Of course, the differences between the national higher education systems also explain their respective advantages and disadvantages.

We are asked to develop a model to assess the health of a system of higher education at a national level to identify a healthy and sustainable state for a given nations higher education system. And we are also asked to propose and analyze policies to migrate a nation from its current state to a proposed healthy and sustainable state.

1.2 Analysis of Problems

For Issue 1 and 2, we develop and verify a model that allows us to evaluate the status of any country's higher education system through this model. Therefore, we take the employment rate and unemployment rate of college students in some countries, the number of the countrys top 1,000 schools in the QS World University, the size of the population with higher education, education investment, the number of international students, the number and quality of papers published as the basis for the model. Then, we build the model through the analytic hierarchy process and fuzzy comprehensive evaluation method. Finally, we give the evaluation index of each country, and select a country with a relatively imperfect higher education system for subsequent analysis.

For Issue 3 and 4, we analyze the countries with relatively imperfect higher education systems selected by the Problem 1 and Problem 2. Our first goal is to find out which indexes of the country lead to the countrys final low score. First, we set a threshold for the health assessment indexes of the higher education system. Then, we obtain the year of the evaluation index when the threshold is exceeded and the value reached by each sub-factor through time series analysis. We use it as a blueprint design indicator for Problem 3. Then we brought these indexes into the model established in Problem 1 and Problem 2 to get the final health evaluation indicators of the higher education system.

For Issue 5, considering the index weights comprehensively, we analyze the two aspects of higher education population size and research quality index. Through the analysis of China's national conditions, we realize that it is impossible for universities to expand enrollment on a large scale in a short time, so we focus on adult higher education. We again use the Analytic Hierarchy Process to develop as quickly as possible to reach the health assessment indicators we set for the higher education system, thereby realizing our vision.

For Issue 6 and 7, We add the impact of the new policy in the evaluation process of selected countries and compare with the original results to verify the effectiveness of our policies.

1.3 Assumption and Notations

We make the following assumptions:

1. There will be no breakthrough progress in the higher education industry in the next 10 years.
2. The country targeted for evaluation will not experience too much turbulence during the evaluation and forecast period and there will be no incidents that overwhelm higher education.
3. The strength of universities in the countries involved in the evaluation will not fluctuate too much during the evaluation and prediction period.
4. During the evaluation and prediction period, no unexpected events will cause significant changes in the evaluation indexes in the model.

Important notations used in this paper are listed in Table 1.

Table 1: The notation we use in the discussion

Symbol	Meaning
R_{em}	employment rate
R_{un}	unemployment rate
$\rho_{foreign}$	proportion of international students
ρ_{high}	population size in higher education
P_j	index of the number of papers
C_j	index of the number of citations
E_j	index of the number of important achievements
EP_j	index of the share of important achievements
EC_j	index of the average citations per article

2 Hierarchical Analysis

We build a Hierarchical Analysis Model in this section. According to the established model, we use the Analytic Hierarchy Process to transform the assessment of the health of the national higher education system into a comparison of various indexes of the country.

2.1 Indexes in Analytic Hierarchy Process

We define six indexes in this section and apply them to the Analytic Hierarchy Process. They are shown in blue in Figure 1. Then, considering that the level of scientific research can reflect the level of a country's education system, we add five indexes to the analytic hierarchy process according to reference [1]. They are shown in red in Figure 1.

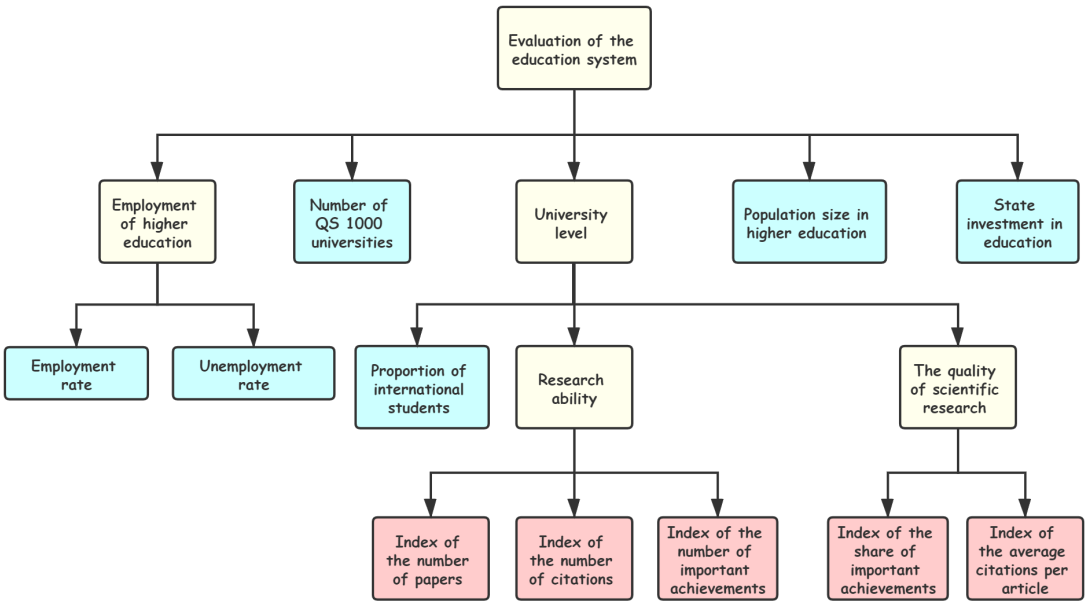


Figure 1: Indexes in Analytic Hierarchy Process

1. Employment rate and unemployment rate of people with higher education

   We define the employment rate and unemployment rate of people with higher education to reflect their employment situation. The employment rate is shown in Formula1 and the unemployment rate is shown in Formula 2.

$$R_{i_{em}} = \frac{N_{i_{em}}}{N_i}, \tag{1}$$

$$R_{i_{un}} = \frac{N_{i_{un}}}{N_i}, \tag{2}$$

   where $N_{i_{em}}$ refers to the the number of employed people with higher education in country i, $N_{i_{un}}$ refers to the number of people with higher education who are unemployed but have labor in country i and N_i refers to the total number of educated people in country i.

2. Number of QS 1000 universities

   We can get the number of top 1000 universities in the QS World University Rankings owned by each country on the website[1]. Because it can reflect the top level of higher education in a country, we define it as an index of the Analytic Hierarchy Process.

3. Proportion of international students

   The large number of international students in a country shows that this country has an all-round, multi-level and wide-ranging education opening pattern. So we use the proportion of international students as one of the indexes, which is shown in Formula 3.

$$\rho_{i_{foreign}} = \frac{N_{i_{foreign}}}{N_i}, \tag{3}$$

[1]https://www.qs.com/rankings/

where $N_{i_{foreign}}$ refers to the number of international students in country i and N_i refers to the total number of students in country i.

4. Population size in higher education

   Population size in higher education can reflect the universality of education in a country and is an important criterion for whether the education system is healthy and sustainable. Therefore, we integrate the country's higher education population and the country's comprehensive development level and use it as an index of the Analytic Hierarchy Process.

5. State investment in education

   The country's investment in education reflects the country's attitude towards education and also plays an important role in the healthy and sustainable development of the country's education system. Therefore, we incorporate it into the Analytic Hierarchy Process.

6. Index of the number of papers

   The country's index of the number of papers is the sum of the indexes of its various subject. The index of each subject is its share in the world. Therefore, the index of the number of papers of country j can be defined as Formula 4.

$$P_j = \sum_{i=1}^{n} \frac{P_{ij}}{P_{iw}}, \tag{4}$$

   where n is the number of subjects, P_{ij} is the number of papers in subject i in country j and P_{iw} is the total number of papers in subject i in the world.

7. Index of the number of citations

   The country's index of the number of citations is the sum of the indexes of its various subject. The index of each subject is its share in the world. Therefore, the index of the number of citations of country j can be defined as Formula 5.

$$C_j = \sum_{i=1}^{n} \frac{C_{ij}}{C_{iw}}, \tag{5}$$

   where C_{ij} is the number of citations in subject i in country j and C_{iw} is the total number of citations in subject i in the world.

8. Index of the number of important achievements

   The country's index of the number of important achievements is the sum of the indexes of its various subject. The index of each subject is its share in the world. Therefore, the index of the number of important achievements of country j can be defined as Formula 7.

$$E_j = \sum_{i=1}^{n} \frac{IP'_{ij}}{IP_{iw}}, \tag{6}$$

   where IP'_{ij} is the number of important achievements published by corresponding authors in subject i in country j and IP_{iw} is the total number of important achievements in subject i in the world.

9. Index of the share of important achievements

   The share of important achievements is the ratio of the number of important achievements to the number of all papers. It can be used to measure the efficiency of the output of important achievements in the country. The country's index of the share of important achievements is the sum of the indexes of its various subject. The index of each subject is its share in the world. Therefore, the index of the share of important achievements of country j can be defined as Formula 7.

$$EP_j = \sum_{i=1}^{n} \frac{\left(IP'_{ij}/P'_{ij}\right)}{\left(IP_{iw}/P_{iw}\right)}, \tag{7}$$

   where IP'_{ij} is the number of important achievements published by corresponding authors in subject i in country j, P'_{ij} is the number of paper published by corresponding authors in subject i in country j, IP_{iw} is the total number of important achievements in subject i in the world, P_{iw} is the total number of paper in subject i in the world.

10. Index of the average citations per article

    The average citations is used to evaluate the average academic impact of each paper and it can reflect the output efficiency of national academic influence. The country's index of the average citations per article is the sum of the indexes of its various subject. The index of each subject is its share in the world. Therefore, the index of the average citations per article of country j can be defined as Formula 8.

$$EC_j = \sum_{i=1}^{n} \frac{(C_{ij}/P_{ij})}{(C_{iw}/P_{iw})}, \tag{8}$$

    where P_{ij} is the number of paper subject i in country j, C_{ij} is the number of citations in subject i in country j, P_{iw} is the total number of paper in subject i in the world and C_{iw} is the total number of citations in subject i in the world.

2.2 Construct hierarchy structure and judgment matrices

We decompose the problem into two levels, as shown in Figure 2. One layer is the objective layer, that is, the evaluation system of the health of the national higher education system. The other layer contains three criterion layers, including the eleven indexes mentioned in Section 2.1 and the comprehensive indexes composed of them.

Based on expert evaluation results, we compare the importance of each element of the criterion layer to the upper layer and construct five judgment matrices as shown in Figure 3. The last row of each matrix is the value of consistency ratios.

2.3 Consistency test and index weight

Because all consistency ratios CR in Figure 3 are all less than 0.1, we believe that the consistency of all judgment matrices is acceptable. Therefore, we do not need to modify the judgment matrices.

After that, we calculate the weights of each index of each layer as shown in Figure4. The weights of these indexes will be used in Section 3.

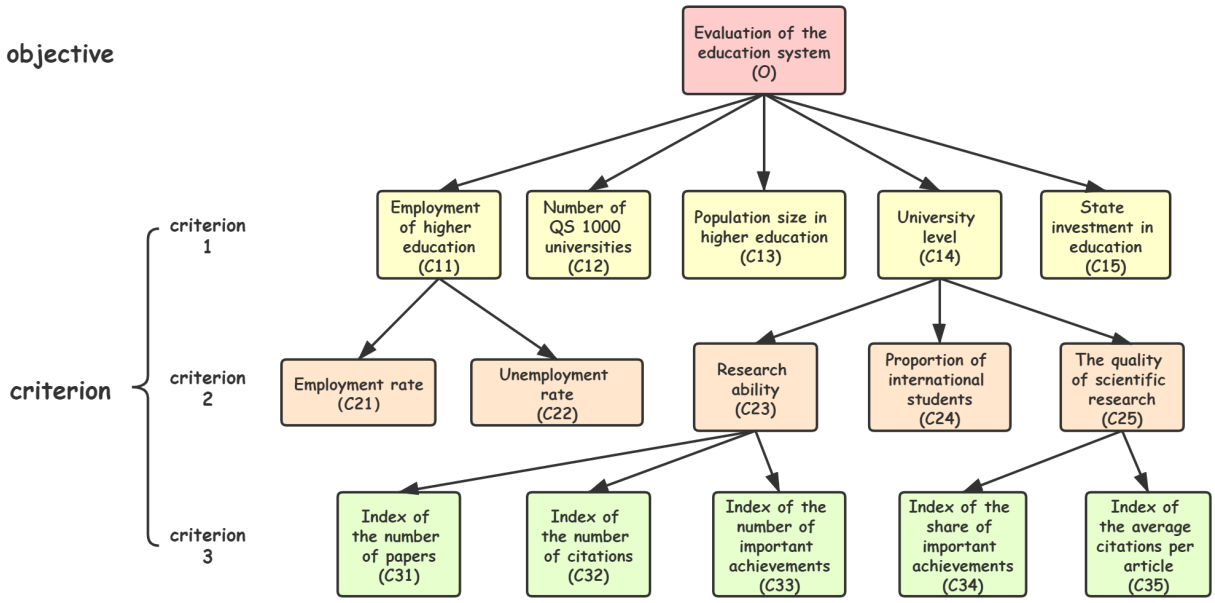


Figure 2: Hierarchical structure in Analytic Hierarchy Process

3 Fuzzy Comprehensive Evaluation

In this section, we use the Fuzzy Comprehensive Evaluation Method to evaluate the health and sustainability of the higher education systems in several countries we selecte. We select appropriate evaluation objects, factor sets, and membership functions, and combine the index weights obtained in Section 2.

3.1 Evaluation object and factor set

We set O={1, 2, 3, 4} to represent the health of the higher education systems in four countries: Canada, the United States, Switzerland and China.

According to the expert evaluation method, we use part of the indexes used in the Analytic Hierarchy Process in Figure 1 as the factor set. The weight corresponding to the factor has been obtained by the Analytic Hierarchy Process and the result is shown in Figure 4.

3.2 Selection of membership function

We choose Cauchy Distribution as the membership function. The membership function of C22 is shown in Formula 9, and the membership functions of other indexes are shown in Formula 10.

$$M_1(x) = \begin{cases} 1, & x \le a \\ \frac{1}{1+\alpha(x-a)^\beta}, & x \ge a \end{cases} \tag{9}$$

$$M_2(x) = \begin{cases} 0, & x \le a \\ \frac{1}{1+\alpha(x-a)^\beta}, & x \ge a \end{cases} \tag{10}$$

where a, α and β are obtained through expert evaluation and data analysis. The results of different factors are shown in Table 2.

O	C11	C12	C13	C14	C15
C11	1	1/4	1/8	1/2	1/6
C12	4	1	1/5	2	1/2
C13	8	5	1	7	4
C14	2	1/2	1/7	1	1/4
C15	6	1/2	1/4	4	1
CR	0.0325				

(a) Judgment matrix of criterion 1

C11	C21	C22
C21	1	3
C22	1/3	1
CR	0	

C14	C23	C24	C25
C23	1	5	3
C24	1/5	1	3
C25	1/3	1/3	1
CR	0.0279		

(b) Judgment matrix of criterion 2

C23	C31	C32	C33
C31	1	1/3	1/3
C32	3	1	1
C33	3	1	1
CR	0.037		

C25	C34	C35
C34	1	1
C35	1	1
CR	0	

(c) Judgment matrix of criterion 3

Figure 3: Judgment matrices

3.3 Fuzzy comprehensive evaluation results of countries

Through the websites of the official statistics bureaus of Canada[2], the United States[3][4], Switzerland[5] and China[6], we obtain the specific values of the factor sets. Then we calculate the membership degree of each factor in each country and the result is shown in Figure 5. So we get the evaluation matrix **R** as shown in Formula 11.

[2]https://www.statcan.gc.ca/
[3]https://nces.ed.gov/
[4]http://www.census.gov/
[5]https://www.bfs.admin.ch/bfs/de/home.html
[6]http://www.stats.gov.cn/

Index	C11	C12	C13	C14	C15
Index weight	0.0423	0.1287	0.5387	0.0694	0.2209

(a) Index weight of criterion 1

Index	C21	C22
Index weight	0.75	0.25

Index	C23	C24	C25
Index weight	0.115	0.4769	0.4055

(b) Index weight of criterion 2

Index	C31	C32	C33
Index weight	0.1047	0.637	0.2583

Index	C34	C35
Index weight	0.5	0.5

(c) Index weight of criterion 3

Figure 4: Index weight

Table 2: a, α and β of factors

Factors	**C12**	**C13**	**C15**	**C21**	**C22**	**C24**	**C31**	**C32**	**C33**	**C34**	**C35**
a	2.2	3.8	4.2	85	3.2	1.5	1	1	2	16	20
α	11.8	4.4	7.3	2.6	6	0.75	2	2	3	100	16
β	-2	-2	-2	-2	2	-2	-2	-2	-2	-2	-2

$$\mathbf{R} = \begin{bmatrix} 0.0134 & 0.9340 & 0.8848 & 0.6627 & 0.0551 & 0.8365 & 0.0000 & 0.0196 & 0.0000 & 0.7407 & 0.7575 \\ 0.9392 & 0.6624 & 0.9218 & 0.8329 & 1.0000 & 0.9194 & 0.8827 & 0.9566 & 0.9179 & 0.8970 & 0.8849 \\ 0.0000 & 0.9193 & 0.9164 & 0.7759 & 0.9434 & 0.7154 & 0.0000 & 0.0000 & 0.0000 & 0.9319 & 0.9007 \\ 0.2532 & 0.8798 & 0.8922 & 0.7639 & 0.4858 & 0.4302 & 0.8657 & 0.7132 & 0.5665 & 0.0359 & 0.1984 \end{bmatrix} \tag{11}$$

After the Analytic Hierarchy Process in the Section 2, we obtain the weights corresponding to these factors. We normalize it and form a weight vector **A** as shown in Formula 12.

$$\mathbf{A} = \begin{bmatrix} 0.0295 & 0.1234 & 0.0506 & 0.1718 & 0.0573 & 0.1093 & 0.0240 & 0.1459 & 0.0592 & 0.1145 & 0.1145 \end{bmatrix} \tag{12}$$

According to $\mathbf{B} = \mathbf{A} \cdot \mathbf{R}^T$, we get the final judgment result **B** as shown in Formula 13.

$$\mathbf{B} = \begin{bmatrix} 0.7703 & 0.7912 & 0.7827 & 0.7545 \end{bmatrix} \tag{13}$$

O	C12	C13	C15	C21	C22	C24	C31	C32	C33	C34	C35
Canada	0.0134	0.9340	0.8848	0.6627	0.0551	0.8365	0.0000	0.0196	0.0000	0.7407	0.7575
USA	0.9392	0.6624	0.9218	0.8329	1.0000	0.9194	0.8827	0.9566	0.9179	0.8970	0.8849
Switzerland	0.0000	0.9193	0.9164	0.7759	0.9434	0.7154	0.0000	0.0000	0.0000	0.9319	0.9007
China	0.2532	0.8798	0.8922	0.7639	0.4858	0.4302	0.8657	0.7132	0.5665	0.0359	0.1984

Figure 5: Membership degree of each factor in each country

It can be seen from the calculation results in Figure 6 that the higher education system in the United States is the most healthy and sustainable, followed by Switzerland and Canada. China's higher education system is the most unhealthy and has a lot of room for improvement.

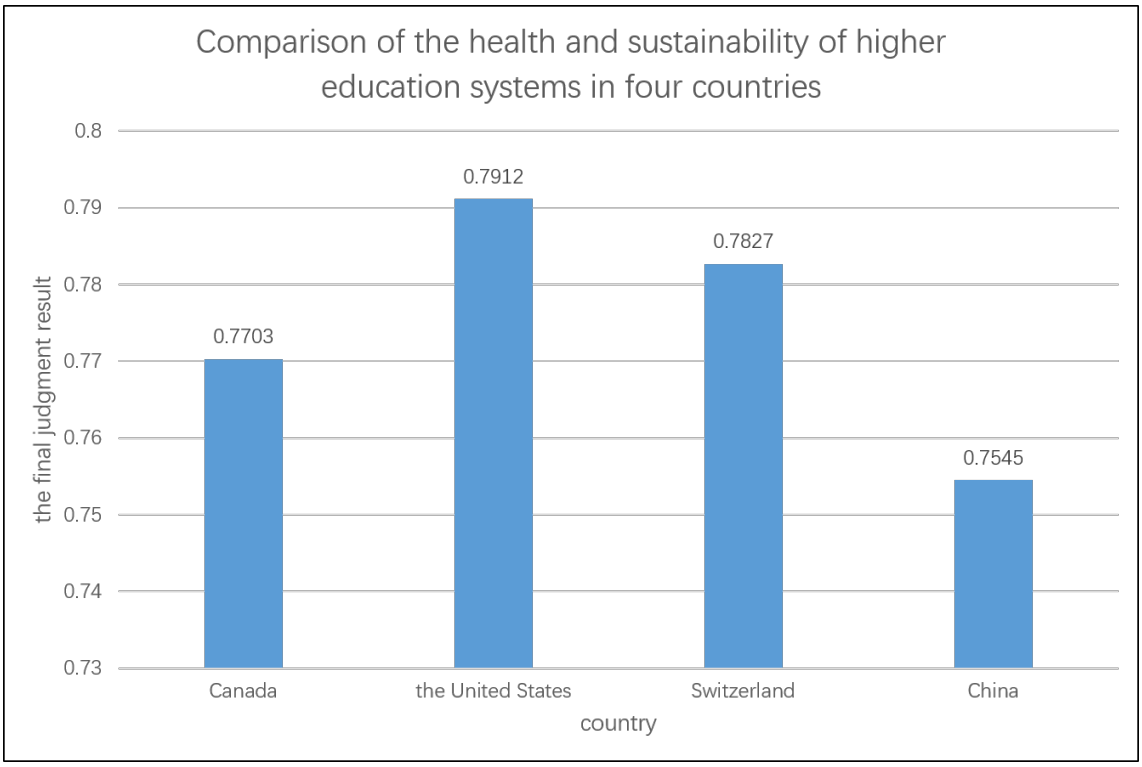


Figure 6: Comparison of the health and sustainability of higher education systems in four countries

4 Vision and measurement of China's higher education system

In this section, we use the models established in Sections 2 and 3 to evaluate China's higher education system. We build a Time Series Forecasting Model to predict China's

various indexes. We use Switzerland indexes as thresholds. When China's indexes exceed those of Switzerland, we believe that China's higher education system has reached a healthy and sustainable state and that this is an achievable and reasonable vision.

4.1 Time Series Forecasting Model

In order to set a reasonable threshold for China's higher education system, we conduct a Time Series Analysis on it. We collect various indexes of China from 2011 to 2019 as shown in Table 3. And the research quality index is the sum of the index of the share of important achievements and index of the average citations per article in Figure 2.

Table 3: Indexes of China from 2011 to 2019

	Percentage of population in higher education	Research quality index	Employment rate of college students	Unemployment rate of college students	Proportion of international students	Number of QS1000 universities	Number of Nobel Prizes	Proportion of National Education Investment
2011	5.96%	54.22	87.82%	5.08%	5.18%	30	1	5.10%
2012	8.47%	55.31	87.66%	4.65%	5.22%	30	2	5.03%
2013	11.15%	56.93	87.16%	4.43%	5.40%	32	2	5.07%
2014	13.54%	57.79	88.35%	4.41%	5.35%	35	2	5.13%
2015	15.98%	57.47	88.09%	4.34%	5.44%	37	3	5.11%
2016	17.80%	57.66	88.23%	4.20%	5.43%	36	3	5.21%
2017	20.35%	58.16	88.39%	3.90%	5.81%	37	3	5.12%
2018	22.22%	58.46	88.68%	3.80%	5.61%	39	3	5.02%
2019	24.14%	58.34	88.30%	3.62%	4.47%	42	3	5.09%

We filter the above data and select two indexes that are lower than the average and change significantly. They are the proportion of the population in higher education and the research quality index. We conduct a Time Series Analysis of these two data and use the assessment indexes for Switzerland in 2020 as their threshold. Since other indexes have remained almost unchanged in recent years, we slightly disturb these data and the Nobel Prize will increase with a very small probability. When China's indexes exceed the threshold set, we believe that China's higher education system has reached our vision. According to the model obtained in Section 2 and 3, we get the evaluation result of China at this time.

We use the Damped Trend Model for Time Series Forecasting and its expression is shown in Formula 14.

$$\begin{cases} l_t = \alpha x_t + (1-\alpha)\left(l_{t-1} + \phi b_{t-1}\right), & \text{horizontal smoothing equation} \\ b_t = \beta\left(l_t - l_{t-1}\right) + (1-\beta)\,\phi b_{t-1}, & \text{trend smoothing equation} \\ \hat{x}_{t+h} = l_t + \left(\phi + \phi^2 + \ldots + \phi^h\right), & \text{prediction equation} \end{cases} \tag{14}$$

where l_t refers the estimated level at time t, b_t refers the predicted trend at time t, $\hat{x}_{t+h}$ refers the prediction result at time t, α refers to the horizontal smoothing parameter, β refers to the trend smoothing parameter and ϕ refers to the damping parameter. The Damping Trend Model is obtained by adding a damping effect to the Holt Model, which can be used to alleviate a higher linear trend.

4.2 Forecast results of indexes in China

We substitute the indexes of the proportion of the population of higher education and the quality of scientific research into the model proposed in Section 4.1, and obtain

the time series analysis results of these two indexes from 2011 to 2030. The prediction results of the proportion of the population in higher education are shown in Table 4 and Figure 7. The prediction results of the research quality index are shown in Table 5 and Figure 8.

Table 4: The forecast of propotion of population with higher education

2011	2012	2013	2014	2015
5.96%	8.47%	11.15%	13.54%	15.98%
2016	**2017**	**2018**	**2019**	**2020**
17.80%	20.35%	22.22%	24.14%	26.22%
2021	**2022**	**2023**	**2024**	**2025**
28.07%	29.87%	31.62%	33.32%	34.97%
2026	**2027**	**2028**	**2029**	**2030**
36.57%	38.13%	39.65%	41.13%	42.56%

Table 5: The forecast of research quality

2011	2012	2013	2014	2015
54.22	55.31	56.93	57.79	57.47
2016	**2017**	**2018**	**2019**	**2020**
57.66	58.16	58.46	58.34	58.88
2021	**2022**	**2023**	**2024**	**2025**
59.39	59.44	59.66	60.03	60.32
2026	**2027**	**2028**	**2029**	**2030**
60.58	60.88	61.21	61.45	61.72

Based on the predicted data, we use the model obtained in Section 2 and 3 to evaluate the health and sustainability of China's higher education system from 2020 to 2030. We get the final judgement result as shown in Table 6 and Figure 9.

Table 6: The forecast of the final judgment result

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.755	0.758	0.763	0.768	0.773	0.775	0.777	0.778	0.779	0.782	0.784

According to Figure 9, we can see that the final evaluation result of the health and

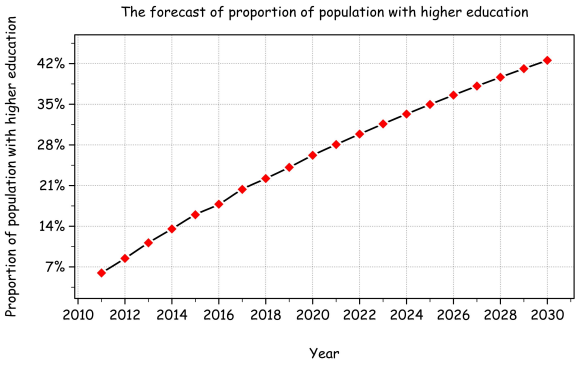


Figure 7: The forecast of population with higher education

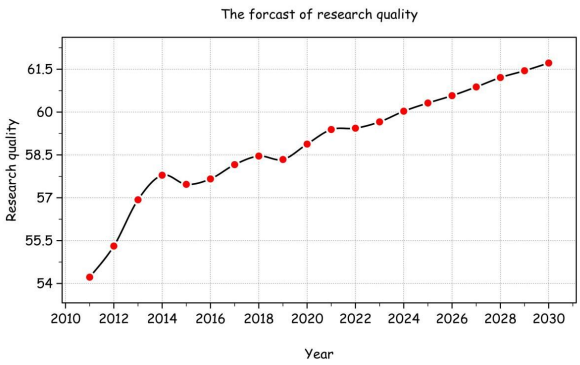


Figure 8: The forecast of research quality

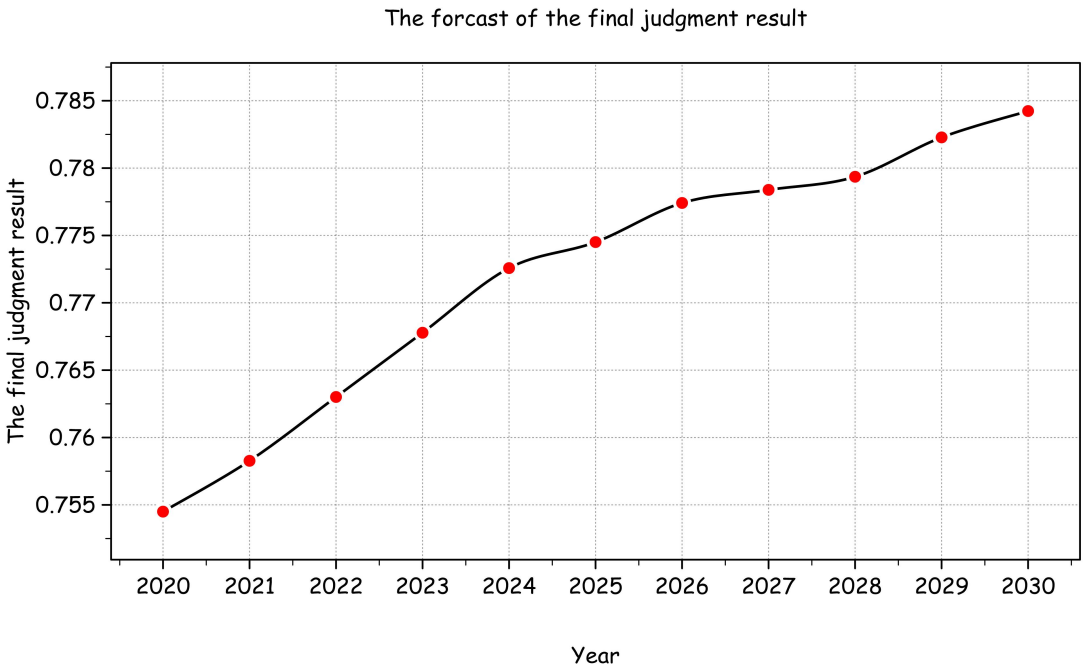


Figure 9: The forecast of the final judgment result

sustainability of China's higher education system in 2030 has reached 0.7842, surpassing Switzerlands 0.7827. Therefore, we believe that by increasing the proportion of the higher education population and the quality of research, China's higher education system can become healthier and more sustainable. China's evaluation index can increase from 0.7545 in 2020 to 0.7842 in 2030. And we selected 42.56% of the population with higher education and 61.72 of the research quality index as an attainable and reasonable vision.

5 Policies and Implementation Timeline

In this section, we propose policies for Chinese enterprises and universities to address the shortcomings of China's higher education system. We hope that these targeted policies can help the Chinese education system to develop in a healthy and sustainable direction. We have also set a specific implementation timetable for the growth of the population with higher education and the growth of research quality to help China make improvements from the current state.

5.1 Policies for enterprises and universities

1. Cooperation between enterprises and universities

   Because the number of college students enrolled every year cannot increase significantly, we are considering strengthening adult education. Therefore, we need the cooperation of enterprises [2]. We propose that companies can discuss with the school and combine the strong courses of the school to develop practical online courses. Teachers teach to adults in the form of online courses, which not only adapts to the rhythm of adult life, but also increases the flexibility of the course. Since this kind of online courses mainly face the social population, the requirements for theoretical knowledge should be reduced, and the requirements for practical operation ability should be increased. In terms of course assessment,

the school will qualify for the exam for students who have completed the online course, and will hold an exam every six months. For students with excellent test scores, the school can issue certification, and the company can give these students a policy preference when recruiting. Because this kind of online course covers part of the professional knowledge of the major and is hosted by the university, we think it is part of higher education.

The above policies can effectively increase the number of people receiving higher education by strengthening adult education, and will greatly help increase the proportion of China's higher education population. At the same time, cooperation between enterprises and schools will also promote the integration of the scientific research results of the two, thereby improving the quality of scientific research in China.

2. Cultivating students by category in universities

   According to the UNESCO International Education Classification Standard[3], higher education can be divided into A and B types. Type A is theoretical and type B is professional. And type A can be subdivided into two categories. One category is set up for preparing research-oriented students, and the other category is not research-oriented students but application-oriented students in various majors. Therefore, we propose that universities should divide courses into two categories according to the development direction of their students. The first type of courses emphasizes the research of basic knowledge and aims to cultivate theoretical students. Another type of courses emphasizes the application of knowledge, with the purpose of cultivating high-level practitioner in various majors.

   If universities train students in different categories and classify courses accordingly, students can receive education that is more suitable for them. If students can receive a more appropriate education, then they are more likely to develop better in their own direction. This will not only reduce dropouts and other similar phenomena and further increase the population with higher education, but also makes students more likely to produce high-quality research results, thereby improving the quality of Chinese research.

5.2 Timetable for population growth with higher education

5.2.1 The expected size of population with higher education

We first predict the population of China from 2020 to 2030. Then, we get the scale that China's higher education population needs to reach each year based on the analysis results in Figure 7. Next, we calculate the number of people with higher education that China needs to increase each year. The results are shown in Table 7.

5.2.2 Higher education population promoted by policies

Regardless of the policies we put forward in Section 5.1, we predict the actual increase in China's population with higher education each year from 2020 to 2030. The results are shown in Table 8.

The sum of the expected annual increase of higher education population in Table 7 is 249,485,319 million. The sum of the actual annual increase of higher education

Table 7: Expected annual increase of higher education population (ten thousand)

2021	**2022**	**2023**	**2024**	**2025**
2731.491955	2675.392449	2620.693919	2567.139705	2515.039705
2026	**2027**	**2028**	**2029**	**2030**
2464.135391	2414.307306	2365.866282	2318.404446	2272.382028

Table 8: Actual annual increase of higher education population (ten thousand)

2021	**2022**	**2023**	**2024**	**2025**
1731.1383	1800.8468	1873.3623	1948.7979	2027.271
2026	**2027**	**2028**	**2029**	**2030**
2108.904	2193.8242	2282.1639	2374.0609	2469.6583

population in Table 8 is 208,100,276 million. Therefore, our policies need to promote higher education for 41,348,258 million people and we can distribute this number on an annual basis.

5.2.3 Policy requirements for each province

Because of the differences in the strength of each province in China, the policies have different effects on the increase of the population with higher education in different provinces.

We use the same Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation Model as Section 2 and Section 3 to score each province in China. The hierarchical structure diagram of the Analytic Hierarchy Process is shown in Figure 10. The comparison matrix composed of various indexes is shown in Figure 11. The weight of each index obtained by Fuzzy Comprehensive Evaluation according to the comparison matrix is shown in Figure 12. Finally, we get the scores of each province as shown in Figure 13.

According to the scoring results of the provinces in Figure 13, our policy sets requirements for the number of people with higher education in each province every five years, as shown in Table 14.

We show the changing trends of the fifth and tenth years on the map of China, as shown in Figure 15.

5.3 Timetable for growth of research quality

Under the premise of smooth implementation of the policy, we use the Time Series Forecasting Model obtained in Section 4.1 to predict China's research quality index from 2021 to 2030 and treat the results as the timetable . The results are shown in Table 9. We compare the research quality index of China from 2021 to 2030 in which the policy is implemented and the policy is not implemented, and the results are shown in Figure 16. It can be seen from the Figure 16 that the implementation of policies can effectively improve the quality of research in China, thereby helping China's higher

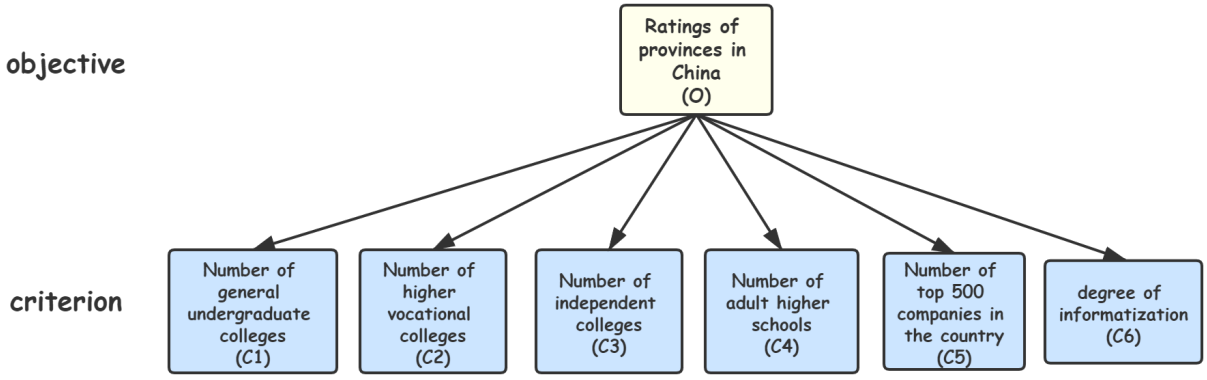


Figure 10: Hierarchical structure in Analytic Hierarchy Process of provinces

O	C1	C2	C3	C4	C5	C6
C1	1	4	3	6	1	1
C2	1/4	1	1/2	2	1/4	1/4
C3	1/3	2	1	3	1/3	1/3
C4	1/6	1/2	1/3	1	1/6	1/6
C5	1	4	3	6	1	1
C6	1	4	3	6	1	1

Figure 11: Judgment matrix of provinces

Index	Index weight
C1	0.2645
C2	0.0652
C3	0.1019
C4	0.0395
C5	0.2645
C6	0.2645

Figure 12: Index weight of criterion

education system to become healthier and more sustainable. But we also found that from 2021 to 2024, which is the first few years of the policy, China's research quality index is lower than that without the policy. We believe that this is due to the decline in the number of research-oriented students at the beginning of the policy. Because the number of research-oriented students has decreased and the number of applied-oriented students has increased, so research positions have become vacant and the progress of many researches has been slowed down.

6 Evaluation of Effectiveness of the Policies

We have obtained in Section 5.2.2 the increase in the population with higher education promoted by the implementation of the policy, and in Section 5.3 the improvement in the quality of research promoted by the implementation of the policy. Under the premise of smooth implementation of our policies, we use the model proposed in Section 2 and 3 to evaluate the health and sustainability of China's higher education system from 2020 to 2030. The results are shown in Table 10. We compare the health and sustainability of China's higher education system from 2020 to 2030 with and without policy implementation, namely the data in Table 6 and Table 10. The comparison

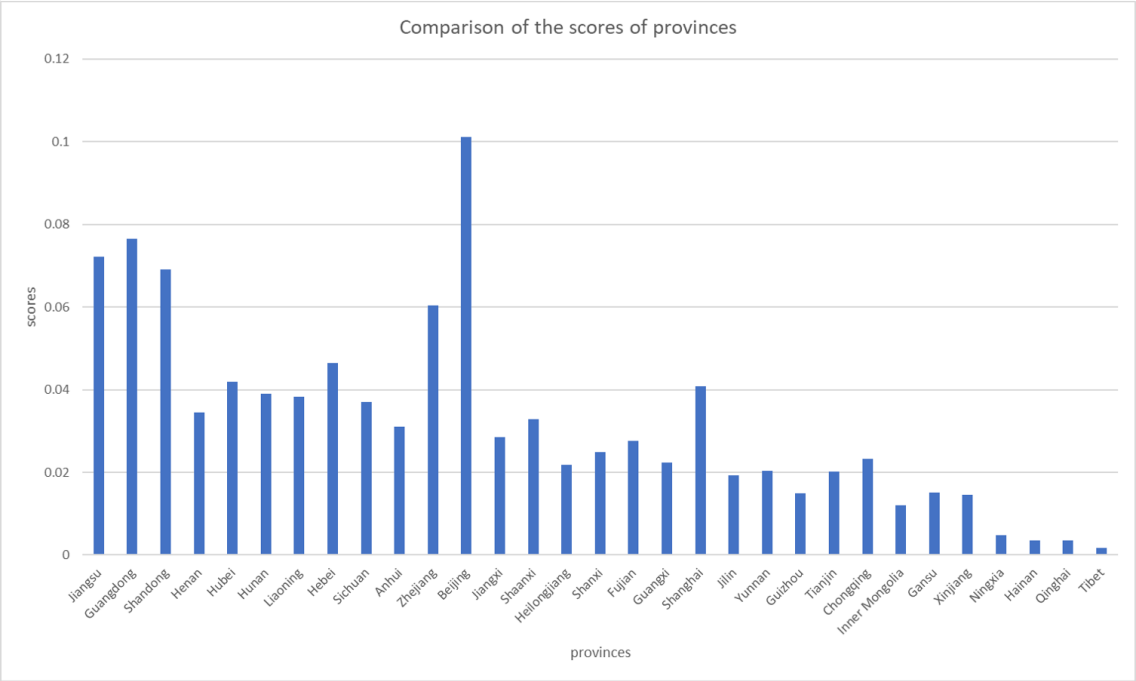


Figure 13: Comparison of the scores of each province

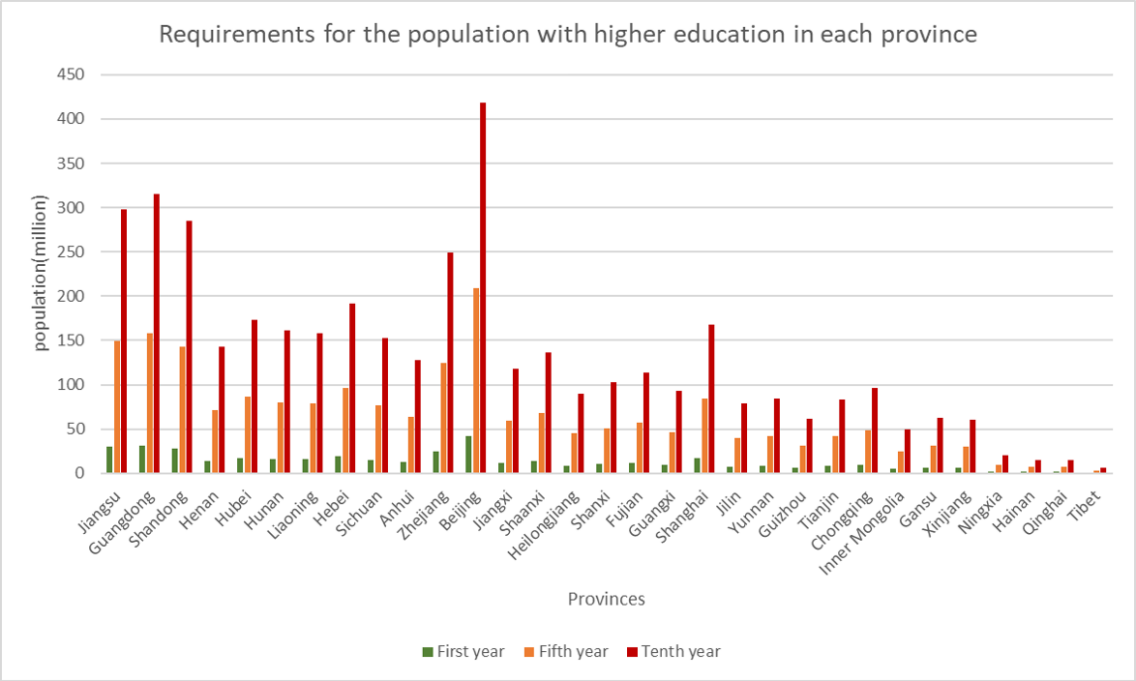
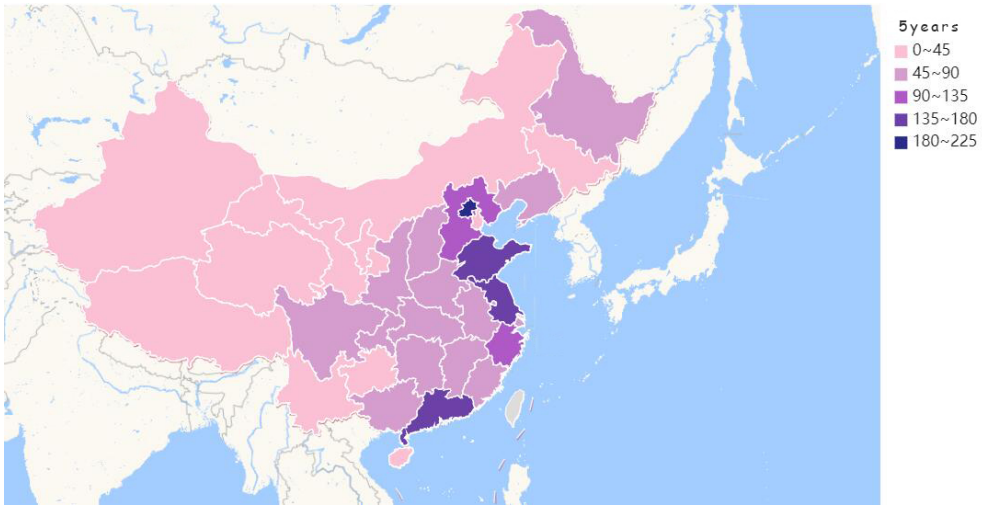
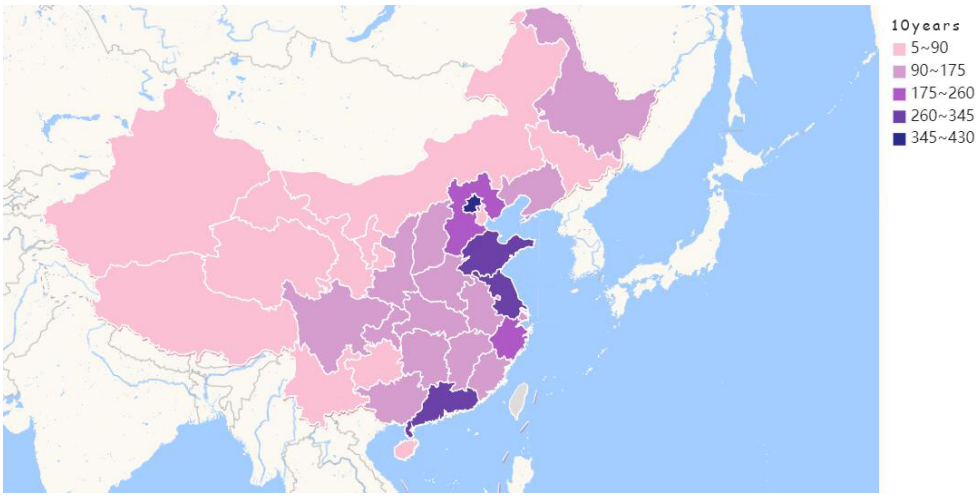


Figure 14: Requirements for the population with higher education in each province

result is shown in Figure 17. From the Figure 17, we can see that after the implementation of the policy, China's scores in each year are higher than the scores without the implementation of the policy. On the one hand, the initial advantages brought by the policy are very obvious, which is reflected in the huge increase in scores brought about by the implementation of the policies in 2020 and 2021. On the other hand, the policy is full of stamina, which is reflected in the fact that the implementation of the policy has greatly increased the slope of the trend line of the score, which makes the scoring gap of whether the policy is implemented reaches 0.2 in 2030.



(a) Requirements in the fifth year



(b) Requirements in the tenth year

Figure 15: Requirements shown on the map of China

Table 9: Expected index of research quality

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
58.70	58.85	59.38	59.74	60.59	61.22	61.48	61.96	62.23	62.99

7 Reform of the Higher Education System is Difficult

Although the reform of the higher education system can bring many positive effects to the country, it also brings many problems in the reform process. We take China as an example to explore the impact and difficulties of higher education system reform in terms of management power ownership and market economy impact. In the discussion, we combined the views on higher education from the many books[4][5][6][7] of Professor Martin Trow.

First, we discuss the ownership of management power. Since the founding of the Peoples Republic of China, Chinas higher education system has basically been centrally managed by the central government, and universities have mainly engaged in

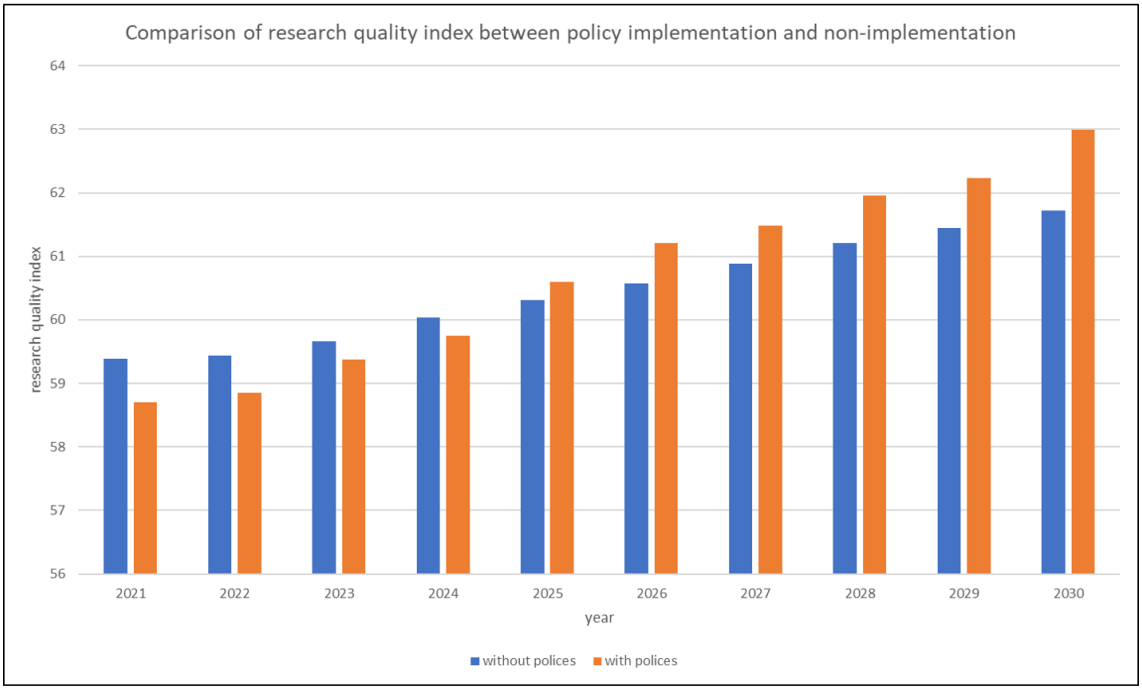


Figure 16: Comparison of research quality index between policy implementation and non-implementation

Table 10: The forecast of the final judgment result with policies

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.768	0.770	0.771	0.773	0.776	0.779	0.785	0.789	0.794	0.799	0.803

coordination work. Under this system, colleges and universities lack enthusiasm for policy implementation, and it is difficult to achieve good results. But if the central government delegates power to universities, problems will also arise. On the one hand, the government's financial allocation to universities will be difficult to assess, which may lead to a mismatch between the finances of universities and their own development. On the other hand, in the case of lack of experience, colleges and universities run academics according to their own needs, leading to confusion in management and development. As a result, the central government had to withdraw its power, leading to the failure of reform. In terms of the policies we put forward in Section 5.1, which universities cooperate with which companies and how to classify courses are big questions. Whether these problems are solved by the universities themselves or the central government will determine to a large extent whether the reform can proceed smoothly and the effect of the reform. Once the wrong decision is made, it will even lead to a decline in the employment rate of a generation, and at the same time lead to insufficient stamina for the country's overall economic development.

Second, we discuss the impact of the market economy on the higher education system. Although the number of higher education institutions in China has been increasing since 1978, it still maintains a planned management model in terms of major decision-making and macro-systems. Higher education is an integral part of the country and has public attributes. But does it have commodity attributes? Can the marketization of higher education be promoted? In terms of the policies we put forward

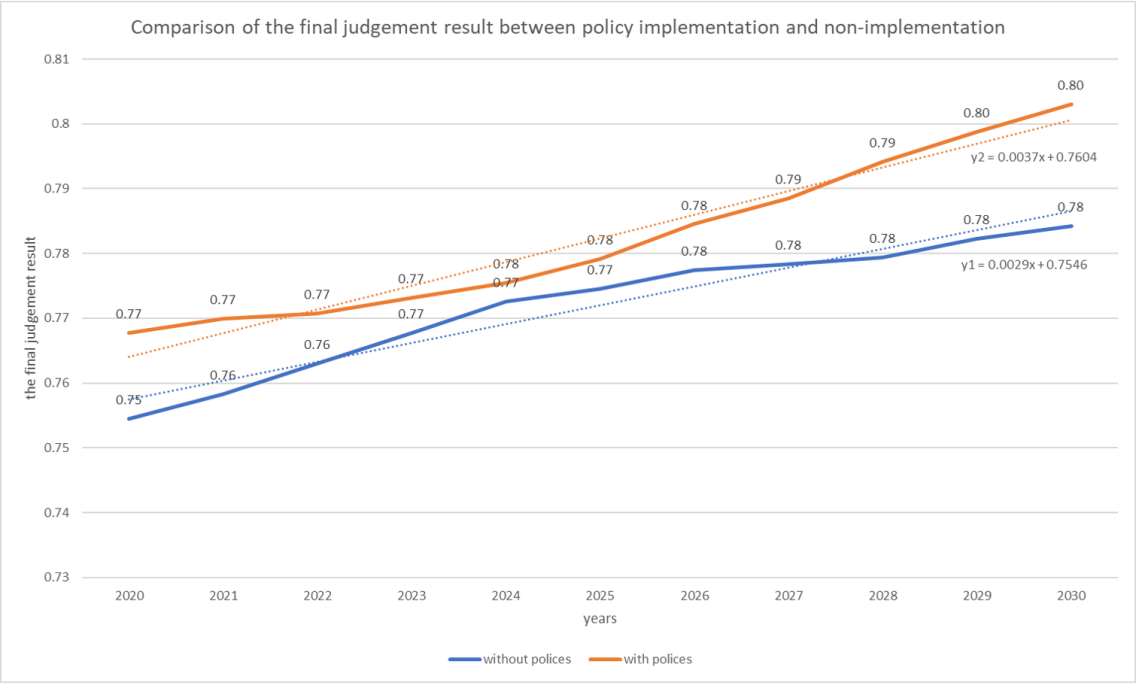


Figure 17: Comparison of the final judgement result between policy implementation and non-implementation

in Section 5.1, will the school cooperate with certain companies for its own economic interests and for the benefit of students? Once a student is forced to work for the enterprise because of the schools policy, this will have a long-term negative impact on the student and his family.

8 Sensitivity Analysis

Since the index weights of Fuzzy Comprehensive Evaluation are obtained by the Analytic Hierarchy Process and the Analytic Hierarchy Process has a certain degree of subjectivity, we fluctuate the two largest weights obtained by the Analytic Hierarchy Process to observe the changes in national scores. Figure 18 and Figure 19 shows the changes in the scores of the four countries when the two largest weights fluctuate between -5% and 5%. It can be seen from Figure 18 and Figure 19 that as the weight fluctuates, the country score fluctuates by 3%. These fluctuations are acceptable in most cases in the actual evaluation, indicating that the model is stable.

9 Advantages and Disadvantages of the Model

9.1 Advantages of the Model

1. Our evaluation model stratifies multiple evaluation indexes. And we process some indexes according to the different levels of national development. This makes the healthy and sustainable development of higher education more suitable for the corresponding national conditions.

2. We incorporate the current hot topic—online education. Teachers use the Internet to teach courses to achieve rapid popularization of higher education. At the same time, this policy, combined with the corresponding examination system, ensure the quality of public learning while rapidly popularizing.

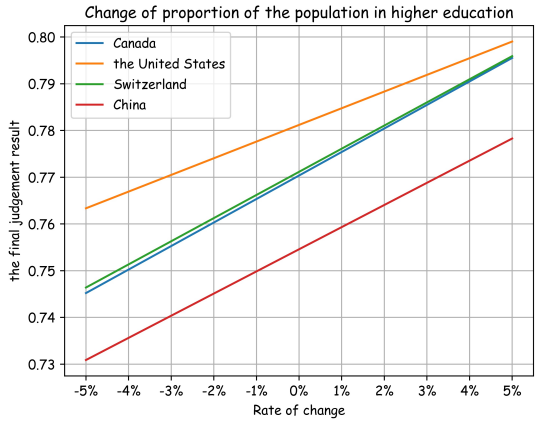


Figure 18: Change of proportion of the population in higher education

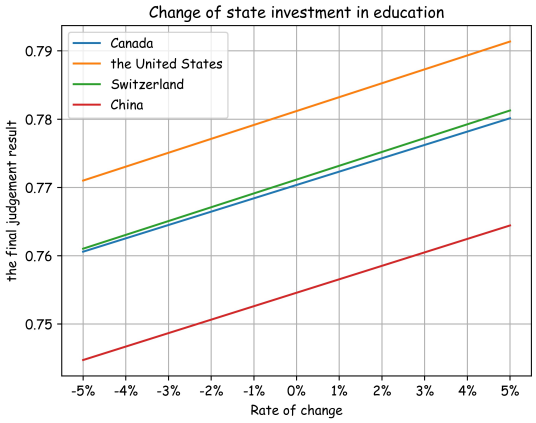


Figure 19: Change of state investment in education

3. We propose a policy of uniting high-tech enterprises and schools. This improves the old learning subjects that are out of the era and reality, and makes learning more practical.

9.2 Disadvantages of the Model

1. We are not comprehensive enough about the unexpected events that may occur in the future.

2. The weight of each index in the model is obtained through paper analysis and data processing. Due to the limited data, there is some subjectivity in the weight setting.

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Appendices

Code for Sensitivity Analysis

```
import numpy as np
from matplotlib import pyplot as plt
from matplotlib.ticker import FuncFormatter

plt.rcParams['font.sans-serif'] = ['Comic Sans MS']
plt.rcParams['axes.unicode_minus'] = True

def to_percent(temp, position):
    return '%1.0f' % (100 * temp) + '%'

u1 = np.mat([
    [0, 0.0196, 0],
    [0.8827, 0.9566, 0.9179],
    [0, 0, 0],
    [0.9020, 0.7239, 0.5665]
]).T
a1 = np.mat([[0.1047, 0.637, 0.2583]])
re1 = a1 * u1

u2 = np.mat([
    [0.7407, 0.7575],
    [0.8970, 0.8849],
    [0.9319, 0.9007],
    [0.0359, 0.1984]
]).T
a2 = np.mat([[0.5, 0.5]])
re2 = a2 * u2

assist = np.mat([0.8365, 0.9194, 0.3046, 0.4302])
u3 = np.stack((re1, re2, assist))
a3 = np.mat([[0.115, 0.4769, 0.4055]])
re3 = a3 * u3

u4 = np.mat([
    [0.6627, 0.0551],
    [0.8329, 1],
    [0.7759, 0.9434],
    [0.7639, 0.4858]
]).T
a4 = np.mat([[0.75, 0.25]])
re4 = a4 * u4

assist = np.mat([
    [0.0134, 0.9392, 0, 0.2532],
    [0.934, 0.6624, 0.9193, 0.8798],
    [0.8848, 0.9218, 0.9164, 0.8922]
])

s = 0.5387
t = 0.2209
x = np.linspace(-0.05, 0.05, 1000)
x_show = np.arange(-0.05, 0.06, 0.01)
ds = s + np.linspace(-s * 0.05, s * 0.05, 1000)
dt = t + np.linspace(-t * 0.05, t * 0.05, 1000)
```

```
result = []

for ii in ds:  # replace ds with dt
    u5 = np.vstack((re4, re3, assist))
    a5 = np.mat([[0.0423, 0.0694, 0.1287, s, ii]])
    # replace s with ii, replace ii with t
    result_per = a5 * u5
    result_per = np.array(result_per)
    result_per = result_per[0]
    result.append(result_per)
result = np.array(result)

Canada = result[:, 0]
US = result[:, 1]
SW = result[:, 2]
China = result[:, 3]

plt.plot(x, Canada, label='Canada')
plt.plot(x, US, label='the United States')
plt.plot(x, SW, label='Switzerland')
plt.plot(x, China, label='China')
plt.xlabel('Rate of change')
plt.ylabel('the final judgement result')
plt.xticks(x_show)
plt.title('Change of state investment in education')
plt.gca().xaxis.set_major_formatter(FuncFormatter(to_percent))
plt.legend()
plt.grid()
plt.show()
```