Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
F		2116279

Higher Education, Future Evolution

Higher education, as the ultimate stage of cultivating the brightest minds and a source of booming economy and prosperous future for a nation, is an incredibly vital issue both as an industry itself and as an impetus for the evolution of us human. The health state of a nation's higher education system is therefore critical. In order to better evaluate it and propose polices as prescriptions for improving it. We have made the following efforts: establishing an assessing model for the health of a nation's Higher Education System (HES) based on which we are able to propose policies to perfect it. We take the HES of the US as an example, evaluate the current and ultimate ideal healthy state of it and propose a series of policies to accomplish the transformation from the current stage to the ultimate ideal stage. Using our models, we are also able to evaluate the effectiveness of our target policies to be implemented and we also discuss the real-world impact of them considering the fact that change is hard. Our detailed works are as follows.

Firstly, to assess the health state of a nation's HES, we first set a series of Health Indicators for Higher Education System (HIHES) divided into two groups, Development Indicator (DI) and Balance Indicator (BI). We utilize the Entropy Theory to weigh each indicator. We determine the DI and BI are equally important so that we give them the equal weight of 50%. All data used to determine the specific weight of second-level indicators can be found on the official website of OECD and WB. We innovatively introduce the GE-Matrix often used in commercial field to build our assessing model. Given a nation's concrete data of 12 indicators involved in DI and BI, we can determine its position in the coordinate system of our modified GE-matrix. We define the difference between the diagonal distance of the GE-Matrix and the distance from the position of a nation's state of HES in the coordinate system to the optimal point (1,1) as the score of a nation's health state of HES. After applying this model to ten countries and grading their HES health state, we select the US as the nation to make further investigations and research. We propose an ideally healthy and sustainable state for the US HES and grade its current health state and the expected state, which is 0.797 and 1.229 respectively, undergoing a 54 % improvement.

Secondly, considering the fact that the US HES is already taking the lead in aspects measured by DI while lagging behind other advanced countries in aspects concerned with BI, we propose the corresponding policies that the US government should first develop aspects concerned with DI and then focus on those measured by BI. We make a prediction for the spontaneous development trend of US HES using the method of Time Series Forecasting. Compared with the spontaneous development of US HES in the GE-Matrix, we are able to derive the effectiveness of our polices to be implemented. We deem that our policies are effective with a huge improvement of 41.3%.

Finally, considering the fact that changes to any institutions or systems are not easy, we discuss the possible real-world impacts of our policies to be implemented both during the transition period and in the ultimate ideal state of US HES from a micro view concerning students, faculty and schools and a macro view at a nation as a whole.

Our model can be utilized to assess quantitatively the health of a nation's HES and to propose targeted policies on a nation's HES based on it. This model may be used to assess the health state of a specific higher education institution as well by omitting the indicators measured from a nation's perspective. It can also be modified to assess the health state of any system by changing the key indicators concerned.

Contents

1 Introduction

"Only the educated are free", said ancient Greek philosopher Epictetus. Education, in the long history of us human being, has played an indispensable role from the very beginning till now. With the overall rapid and robust growth of economy and technology, education becomes more universal and more common. In the meantime, the level of education also grows steadily worldwide. According to the data from the Organization for Economic Cooperation and Development (OECD), in the main advanced economies of the world, G7, mean schooling year has reached 12.6 years in 2017, which is equal to the educational level of freshman year. This is an indicative sign of the forthcoming progress in the world's educational level as a whole towards a scenario where higher education degree would become more prevalent. In fact, the system of higher education has undergone significant progresses in the last decades and has value of being both an industry by its very nature and a source of well-educated and trained citizens to continue booming the economy.

However, being a system, not a single one can be flawless. The system of higher education is no exception. Even in the world's most developing countries such as the United States or Canada, the system of higher education still has a long way to go. *"Right now, three-quarters of the fastest growing occupations require more than a high school diploma. And yet, just over half of our citizens have that level of education, and half of the students who begin college never finish."*[1] said former president Barack Obama in a speech to the Congress on February 24, 2009.

Since the system of higher education is far from perfect, the measures of assessing the health of a higher education system and policies to be implemented to recalibrate it when it is on the wrong track has been a research concern for many for decades. Some aspects of the higher education system have been explored such as equity of higher education. In the article *Equity in Higher Education,* (Robinson J et al.2016), the measurement of equity as an indicator of the state of health of higher education system has been explored. *It has to be recognized that institutional racism and sexism is an entrenched characteristic of higher education system. Equity of higher education is the attainment of a certain proportion of marginalized groups in higher education system in terms of race, skin color, gender and so forth.*[2]

Nevertheless, research like this mainly focuses on a single one or just few indicators judging the health state of higher education system and constrain to qualitative policy solutions to the problems existed. Under the current pandemic, we can see that higher education systems of some nations are resilient while those of some others are vulnerable. Each of these national systems of higher education has its own strengths and weaknesses. To be more aware of what characteristics of these systems are and therefore attain the goal of improving them, an all-round assessment measure of the health of higher education system must be established in a quantitative way, based on which targeted policies can be made. Therefore, following tasks are to be accomplished:

- A comprehensive assessing model is needed. By involving main indicators, the health state of any given nation's higher education system can be measured quantitatively.

- A desirable healthy and sustainable state for any given nation's higher education systems should be able to be derived applying the model established.
- A suite of polices should be able to be proposed with the help of the model established to migrate the higher education system of any nation from its current state to its desirable healthy and sustainable circumstance.

Based on the existent research that have analyzed the basic indicators of the state of health of higher education system and existent qualitative policies repairing and perfecting the higher education system, our research focus on health assessment of higher education system, as well as policies based on quantitative result. Detailed works are as follows:

1) We first create a system of two first-level indicators, Development Indicator (DI) and Balance Indicator (BI) of the health of a nation's higher education system. We utilize entropy theory to weigh each second-level indicators involved in DI and BI to establish a modified GE-Matrix assessing model of higher education system from a nation's perspective.

2) We then apply this model to 10 countries and select the United States as a country that has room for improvement and provide a desirable scenario for a healthy and sustainable higher education system for it. We also score the future ideal state of the US higher education system.

3) We subsequently propose several policies to migrate the US higher education system towards our expected healthy and sustainable state. Effectiveness of our policy are assessed quantitatively by our modified GE-Matrix.

4) We finally discuss the real-world impacts of our targeted policies during the transition and at the end state on the US higher education system from a micro and macro view respectively.

2 Assumption

We assume that the healthier a country's higher education system is, the greater its inertia of development will be, thus leading to a weaker influence of government policies on the development of its higher education system.

3 An assessing Model of Higher Education System

In this section, we first develop a system of Health Indicators for Higher Education System (HIHES). Utilizing the system set up, we then establish a model that allow us to assess the health of any given nation's higher education system. Finally, we score the health of higher education system for ten representative countries around the world.

3.1 Health Indicators for Higher Education System (HIHES)

When selecting the indicators, we deem that the they should be clear, scientific and fully indicative, therefore we keep to the following four principles as our benchmark in the selection of the indicators:

- Systematic principle. Indicator may have internal relationships with one another to form an intertwined system as whole, but they should be specifically defined and can be separated from one another easily and clearly. The indicators altogether should be able to reflect the main characteristics of a higher education system from details to a macro big picture.
- Typical principle. Each indicator must be representative enough and closely related to one aspect of the higher education system, so as to generally reflect the overall health state of a given nation's higher education system.
- Controllable principle. Each indicator must be controllable with certain policies implemented since the object of our research not only focuses on assessing a nation's higher education system, but also concentrates on providing policies that can recalibrate the system when it goes wrong. Therefore, the indicators must be rather controllable for the government to conveniently carry out policies to have considerable positive effects on them.
- Quantifiable principle. In order to facilitate the subsequent model analysis, the indicators must have the characteristics of being quantifiable.

Based on the four principles mentioned above, we then identified twelve health indicators for higher education system. To be more precise, these indicators are divided into two first-level indicators, development indicator and balance indicator. Development indicator refers to those in favor of long-term maintenance and improvement of higher education system while balance indicator measures the harmony, equilibrium and stability of the higher education system.

Specifically, development indicator includes:

(1) Funds & Human Resources Invested Per Capita which measures in dollar terms of the amount of expenditure and human resources as well invested in a common higher education accepter of a nation. (2) Total Public Educational Expenditure which measures the share of higher educational public expenditure in government spending. (3) Share of GERD in GDP which measures the share of gross expenditure of research and development in GDP. (4) Employment Rate of HE Accepters which measures the level of employment after having a higher education degree. (5) Relative Earnings of HE Accepters which measures the level of earnings or returns of a higher education degree

Balance indicator involves: (1) Ratio of Student to Teacher which measures the number of students a teaching staff corresponds to in higher education institutions. (2) School Enrollment Ratio between female and male of higher education institutions, also called gender parity index for gross enrollment ratio in tertiary education, which is the ratio of women to men enrolled at tertiary level in both public and private schools. (3) R&D personnel Number in a Million People which measures the number of researchers engaged in research and development expressed as per million. (4) Share of Labor Force with Higher Education which

measures the percentage of labor force with a degree of higher education among the whole labor force in a nation. (5) Share of International Student in All Students Enrolled which measures the proportion of exchange students from abroad in all students enrolled in higher education institutions. (6) Scientific and Technical Journal Articles Published which measures the scientific and engineering articles published per million people. (7) Higher Educational Personnel Number in a Million People which measures the number of staffs in higher education institutions per million people.

The indicators above, from an all-round and detailed view, identify the health state of a country's higher education system altogether. Our data of these indicators are all derived from the official website of OECD and WB and are available.[3] The URLs are attached in the Reference list.[4]

3.2 A Measurement of Health State of Higher Education

We establish a mathematical model to evaluate the health state of a nation's higher education system. First we make the data normalization, then we use the entropy theory to derive the weight of each indicator. Subsequently, we define the Development Indicator (DI) and the Balance Indicator (BI), and calculate the corresponding values of each second-level indicators involved in DI and BI to reflect the health state of a nation's higher education system in the GE matrix. Finally, we compare the health state of higher education system in ten countries around the world.

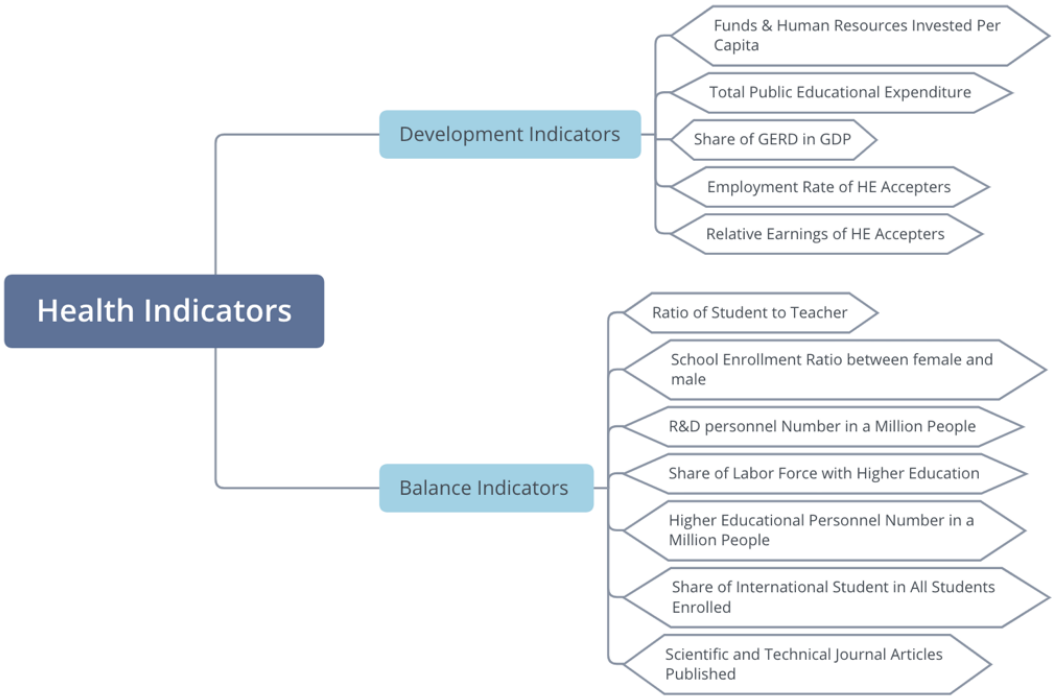

Figure 1 Health System Indicators

3.2.1 Data Normalization

We found that the dimension of each indicator varies significantly, so the data of each indicator must be standardized to establish a model for specific analyses.

Considering the fact that these 12 indicators can be basically divided into three categories: positive indicators, negative indicators and special indicators, we adopt different standardizing treatment methods corresponding to the types of the indicators. Among them, positive indicators have positive effects on the health level, while negative indicators have negative effects on the scores. Special indicators do not have general conclusions and needed to be discussed separately. We assume that there are $m(m = 12)$ indicators and $n(n = 10)$ countries in the system, x_{ij} represents the value of the indicator $j(j = 1,2, \dots, m)$ for the country $i(i = 1,2, \dots, m)$. p_{ij} represents the normalized data of x_{ij}.

When x_{ij} is a positive index we then carry out the forward procedure, which is the following formula:

$$p_{ij} = \frac{x_{ij} - min_j(x_{ij})}{max_j(x_{ij}) - min_j(x_{ij})}$$

Where $max_j(x_{ij})$ represents the maximum value of the index j in n sample countries, and $min_j(x_{ij})$ represents the minimum value of the index j in n sample countries.

For a negative index, we negatively process it with the following formula:

$$p_{ij} = \frac{max_j(x_{ij}) - x_{ij}}{max_j(x_{ij}) - min_j(x_{ij})}$$

For a special index, such as the School Enrollment Ratio between Female and Male, to strive for gender equality, the value of this index should be kept around 1, which is the optimal state. Therefore, we need to carry out special treatment procedure on it. The corresponding standardized formula is as follow:

$$p_{ij} = 1 - \frac{\left|1 - x_{ij}\right|}{\left|1 - x_{ij}\right|_{max_j}}$$

According to the value of each index after standardization above, we calculate the normalized value of each index according to the following equation
:

$$y_{ij} = \frac{p_{ij}}{\sum_{j=1}^{n} p_{ij}}$$

where each normalized index y_{ij} corresponds to a standardized index p_{ij}. By processing the data above, we can appropriately apply them to the model established later.

3.2.2 Indicator Weight

The concept of entropy first emerged in physics as a indicator to describe the degree of disorder of matters. Later, the concept of entropy was also widely used in mathematics. According to the characteristics of Shannon entropy, we can not only measure the randomness and disorder degree of an event, but also judge the dispersion degree of the indicators on the comprehensive evaluation system by entropy value.[5]

The reasons why we use the entropy theory to determine the relative weight of indicators are that the data we need to deal with are discrete ones and that it is difficult to determine the significance of each indicator, which falls into exactly the sphere of application of the entropy theory.

First of all, according to the definition of information entropy, the information entropy S_j of index j can be obtained by using the previously normalized index according to the following formula:

$$S_j = -\frac{1}{\ln n}\sum_{i=1}^{n} y_{ij} \cdot \ln y_{ij}$$

$$where \quad j = 1,2,3,\dots,m;$$

Then the information entropy of index j is used to determine the corresponding weight W_j by the following equation:

$$W_j = \frac{1 - S_j}{\sum_{j=1}^{m}(1 - S_j)}$$

3.2.3 Development Indicator (DI) & Balance Indicator (BI)

Development indicator (DI) and Balance indicator (BI) are utilized to depict the state of health of a given nation's higher education system, where DI concentrates on the ability of the system to renew and improve itself while BI emphasizes on the perfectness and fairness of it. It is only when both DI and BI of a nation's higher education system reach a relatively high level can we deem that the higher education system in this country is healthy and sustainable. Here, we define DI as

$$DI = \boldsymbol{W}_{DI}\boldsymbol{P}_{DI}$$

$$where \quad \boldsymbol{W}_{DI} = \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \end{bmatrix}^T ; \boldsymbol{P}_{DI} = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{bmatrix}$$

The $p_i(i = 1,2,\dots,5)$ component in $\boldsymbol{P}_{DI}$ represents the standardized data corresponding to an indicator i $(i = 1,2,\dots,5)$ of a given nation.

In the same way, we define the Balance Index (BI) as:

$$BI = \boldsymbol{W}_{BI}\boldsymbol{P}_{BI}$$

$$where \quad \boldsymbol{W}_{DI} = \begin{bmatrix} W_6 \\ W_7 \\ W_8 \\ W_9 \\ W_{10} \\ W_{11} \\ W_{12} \end{bmatrix}^T ; \boldsymbol{P}_{DI} = \begin{bmatrix} p_6 \\ p_7 \\ p_8 \\ p_9 \\ p_{10} \\ p_{11} \\ p_{12} \end{bmatrix}$$

The $p_i(i = 6,7,\dots,12)$ component in $\boldsymbol{P}_{DI}$ represents the standardized data corresponding to an indicator $i(i = 6,7,\dots,12)$ of a given nation.

3.2.4 A GE-Matrix to Assess Health of Higher Education System

GE Matrix, created by General Electric in 1970s, is a measure of the competitiveness and appeal of a corporation within the targeted market.[6] It utilizes multiple, various and weighted factors to determine the performance of the competitiveness and appeal of a given company in any given market. It uses ordinal data as a quantitative method to assess the two indicators, competitiveness and appeal. Thus, given concrete data of factors determined beforehand, the performance of a corporation in the market it occupies can be derived rather quantitatively. Further a point lies on the horizontal or vertical axis, the better the corporation performs in the indicator the axis stands for. Therefore, the upper right point of the matrix stands for the optimal state for a company in the market.

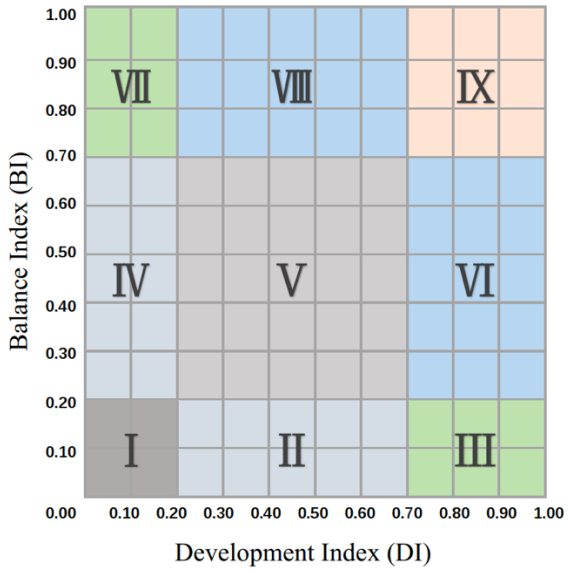

Figure 2 GE-Matrix

Table 1: The explanation of GE-Matrix

Area	DI	BI	State
Ⅰ	0-0.2	0-0.2	Poor health
Ⅱ	0.3-0.7	0-0.2	Balance-biased illness
Ⅲ	0.7-1.0	0-0.2	Balance-biased unhealth
Ⅳ	0-0.2	0.2-0.7	Development-biased illness
Ⅴ	0.2-0.7	0.2-0.7	Sub-optimal sub-health
Ⅵ	0.7-1.0	0.2-0.7	Under-development sub-health
Ⅶ	0-0.2	0.7-1.0	Development-biased unhealth
Ⅷ	0.2-0.7	0.7-1.0	Under-balance sub-health
Ⅸ	0.7-1.0	0.7-1.0	Optimal health

Inspired by the essence of GE-Matrix, we make an analogy to build a modified GE-Matrix measuring the health of a nation's higher education system. Similar as a normal GE-Matrix, we set the two indicators DI and BI altogether as a measurement of the health state of a nation's higher education. Furthermore, the closer the coordinate lies to the upper right point (1,1) of the matrix, the healthier the nation's higher education system is. We therefore define the distance from the coordinate to the upper right point (1,1) as the health level of nation's higher education system. The lower the distance, the higher the health level of the nation's higher education system.

And we defined the score as the longest distance $D_{\max}$ minus the distance from this point to the upper right point (1,1).

$$D_{max} = \sqrt{2}$$

3.3 Results

Using data from the World Bank and the OECD on Development Indicators and Balance Indicators, we scored and ranked the health of 10 representative countries around the world. The ten countries come from different continents and include both developed and less developed countries. Table 3 shows the results based on the actual situation in 2018. The higher the score is, the healthier the higher education system will be. From the results, it can be seen that Sweden has the healthiest higher education system, while that of Mexico is the least healthy one.

Table 2: 2018 Health rankings of 10 countries

Rank	Country	DI	BI	Score
1	Sweden	0.6887	0.7490	1.0144
2	Netherlands	0.6234	0.7198	0.9449
3	Germany	0.6611	0.5662	0.8638
4	Britain	0.4851	0.7291	0.8325
5	America	0.8395	0.4040	0.7970
6	Japan	0.5291	0.4919	0.7215
7	Portugal	0.3570	0.6836	0.6977
8	French	0.4733	0.4723	0.6687
9	Turkey	0.4008	0.3177	0.5063
10	Mexico	0.3074	0.2424	0.3878

It can be seen from the results presented by the table above that the United States has an explicit advantage over other countries at DI, which measures the capacity for the system of higher education to further perfect and develop itself. While the health state of the US higher education system is only at an intermediate level taking into account the other indicator BI, which measures the rationality and justice of the system. To be more precise, some subsidiary indicators of BI aren't satisfactory which are Share of Labor Force with Higher Education Background and School Enrollment Ratio between female and male. These two indicators are considerably inferior to other countries with basically the same economic and technological circumstance as the US. Therefore, we consider the system of higher education system for the United States is in a state of sub-health and that the issues concerned with BI especially the Share of Labor Force with Higher Education Background indicator and School Enrollment Ratio between female and male indicator need to be addressed properly and urgently. Taking all above into account, we choose the United States the selected country that his room for improvement in its system of higher education.

A Vision for the System of Higher Education of the US | 4

A healthy and sustainable higher education system of a nation, without doubt, must have relatively high performance in both DI and BI, which means it has a fairly excellent scenario in the higher education system at the initial stage and moreover, it has a strong capacity to align around this scenario and continue to renew or perfect itself.

For the higher education system of the US, we deem that aspects measured by DI are already nearly optimal, so as long as these indicators remain the current level and have steady growths or can even have minor fluctuations but maintain an upward trend in the long run. The outcome is desirable. The aspects concerned with BI for the US higher education system, however, are not satisfactory, therefore the correction of these defects are the major concerns for the US higher education system. To provide a healthy and sustainable vision for US higher education system in

the future, we mainly focus on the improvement on the aspects concerned with less satisfying indicators of BI.

Specifically, for the DI, we have the following analyses:

- For Funds & Human Resources Invested Per Capita, to propose an attainable desirable value for this indicator, we deem that the price level remains stable so that this indicator would be in accordance with the real economic level of the US. We set the desirable value of this indicator as 26500 taking 2018 as the base year measuring the price level of the US.
- For Total Public Educational Expenditure, we consider this indicator as a measurement of the importance government attaching to the cause of higher education. According to the data from the OECD official website, we deem the present share of higher educational expenditure in US government spending is far from reasonable taking into account the US has the largest number of top-ranking higher education institutions. We consider this indicator to grow from the current value of 3.7% to 5% as a reasonable state.
- For Share of GERD in GDP, we consider the optimal value of this indicator of US should match that of the leading countries on this indicator. We deem it to be 4%.
- For Employment Rate of HE Accepters and Relative Earnings of HE Accepters, we assume the higher these two indicators are, the better the state of health US higher education system would be, so we assume these indicators to maintain a steady or upward trend. We set the two indicators at 85% and 180.

For the BI, we have the following analyses:

- For Ratio of Student to Teacher, we assume this indicator to match the world's advanced level which is about 10:1.
- For School Enrollment Ratio between female and male of higher education institutions, considering the current ratio between all female and male in the US, we deem the two ratios should be equal to strive for a balanced healthy higher education system. According to the data from USBC (United States Bureau of the Census), we set the ratio as 1.03.
- For R&D personnel Number in a Million People, we determine this indicator to be rather fair at the value of around eight thousand.
- For Share of Labor Force with Higher Education, we set this indicator at 80% for the reason that there will always be some professions requiring a moderate educational background only.
- For Share of International Student in All Students Enrolled in higher education institutions, we deem that this indicator measures the exchange rate of world's brightest mind. However, the value of this indicator shouldn't be too high for this also measures the native higher education seekers' thoughts about how high the level their nation's higher education is. Therefore, taking into account the data of some nations which are doing well in cultivating students in higher education institutions and embracing a huge amount and wide variety of brilliant minds from all over the world, we set this indicator at 10% as a desirable outcome.

- For Scientific and Technical Journal Articles Published Per Million people, this indicator measures the innovative ability of a nation, also reflecting the higher education level of it, we set this indicator as 2000 based on the current level of 1300 of that indicator.
- For Higher Educational Personnel Number in a Million People, we deem this indicator as a measurement of the cultivation ability of a nation, referring to the current level of advanced countries, we set a desirable vision for this indicator for the US as 20000.

To facilitate understanding, we draw the following table to provide an intuition for the comparison between the current system and the proposed attainable and reasonable vision for the US higher education system.

Table 3: Values of Indicators at Current State and Ideal State of the US HES

	Index	Current	Ideal
DI	Funds & Human Resources Invested Per Capita (10 dollars)	26021	26500
	Total Public Educational Expenditure (%)	3.7	5
	Share of GERD in GDP (%)	2.83	4
	Employment Rate of HE Accepters (%)	83	85
	Relative Earnings of HE Accepters	176	180
BI	Ratio of Student to Teacher	13.8	10
	School Enrollment Ratio between female and male	1.26	1.03
	R&D personnel Number in a Million People	4612	8000
	Scientific and Technical Journal Articles Published	1294	2000
	Higher Educational Personnel Number in a Million People	17701	20000
	Share of Labor Force with Higher Education (%)	73	80
	Share of International Student in All Students Enrolled (%)	5.2	10
	Score	0.797	1.229

We score the current health state and the attainable ideal state of the US HES, which has a 54.23% improvement.

Forecasting and Policy Interventions | 5

In this part, we first forecast the spontaneous development trend of the health level of the US higher education system over the next 20 years. Secondly, we establish a controlled development model to predict the health of higher education system in the United States in the next 20 years with appropriate policy interventions. Finally, we compare the spontaneous outcome and the outcome intervened and further analyze the effectiveness of policy intervention.

5.1 Spontaneous Development Prediction Model

The research on the health level of the US higher education system under the state of natural development in the next 20 years will be helpful for us to put forward more reasonable and effective policies for the US government in the future, which enables us to better cope with the development problems of the US higher education system.

Our predictions for the US higher education system over the period of the next 20 years, based on data from the OECD and the World Bank, are shown in Figure 3 below:

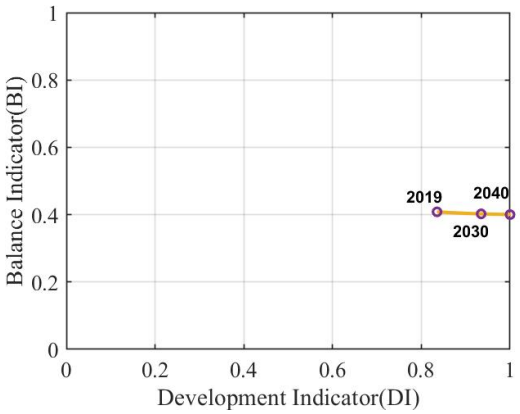

Figure 3 The unconstrained trend

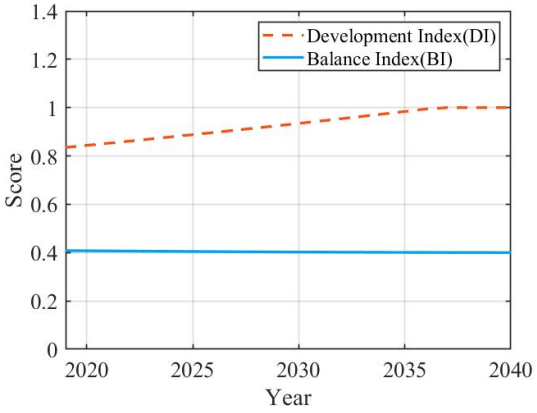

Figure 4 The each of index natural trend

According to the forecast results above, it can be clearly noticed that the health level of higher education system of the United States will develop in one direction over the next 20 years, with DI rising sharply while BI remains basically unchanged and even slightly declines. Therefore, we should pay more attention to policies related to fairness and openness, so as to improve the balanced development of the US higher education system.

5.2 Policy Intervention

We first build a controlled development model and then analyze the changes in the health of the higher education system in the United States over the next 20 years under the influence of policy interventions.

5.2.1 Controlled Development Model

Based on our achievable and reasonable vision of the United States for the next 20 years, we assume that this vision is the ideal development point for the next 20 years and mark it as $A(x_{max}, y_{max})$, At a certain moment the health level of higher education system corresponds to the point in GE matrix for $A_i(x_i, y_i)$. If A_i is closer to A, then it is indicated that the health level of the nation's higher education system at this time is relatively higher, and the influence degree of policy on the development trend will be weaker. Due to the fact that real development trend under the intervention of targeted policies and the ideal scenario has deviations to some extent, we define the impact strength of the policies implemented as the angle θ from the direction of ideal development and that of real development, and that the value of this angle being θ_i at moment i.[7] For convenience, we assume that the angle θ_i at moment i has is a linear function

to the distance $|A_iA|$ from the current health level of higher education system and the optimal level of it. The relationship between the two parameters is described by the following equation:

$$\theta_i = \alpha \cdot |A_iA| + \beta$$

where $\alpha = -9.02$, $\beta = 5.209$. The parameters α and β can be obtained based on the previous data of spontaneous trends in the United States and through fitting methods.

Secondly, it is assumed that the subsequent point of the health state of higher education system after policy intervention is $A_{i+1}(x_{i+1}, y_{i+1})$ in the GE matrix, and the deviation distance $|A_iA_{i+1}|$ equals a fixed value d every time, which is brought about by the policy intervention. We assume that the deviation distance d each time is within the control range of the government and also meets the law of natural development, that is, d does not exceed the maximum of the previous moving distance d_{max}.

$$d \leq d_{max}$$

In order to propose reasonable policies for every time period, we must determine the relation between the length of a vector in the GE matrix and the time. For convenience, we define the ratio of the time under natural trend and the sum of deviation distance as a unit of time. We record it as γ, and γ can be obtained by the following equation:

$$\gamma = \frac{T}{\sum_{i=1}^{t} |A_iA_{i+1}|}$$

Where T represents the total number of years after changes of t times.

Next, we calculate the length of the deviation over the next 20 years, $L = \gamma \cdot T$, where $T = 20$, so we can determine the total number of times n that policies should be implemented , where $n = L/d$. Since d is a controllable fixed value, the increase of d will lead to the decrease of total number of times that policies should be implemented. Therefore there is a need for us to determine an optimal and reasonable value of d so that the health state of the higher education system in the United States can reach the optimal state in 20 years under the intervention of policies.

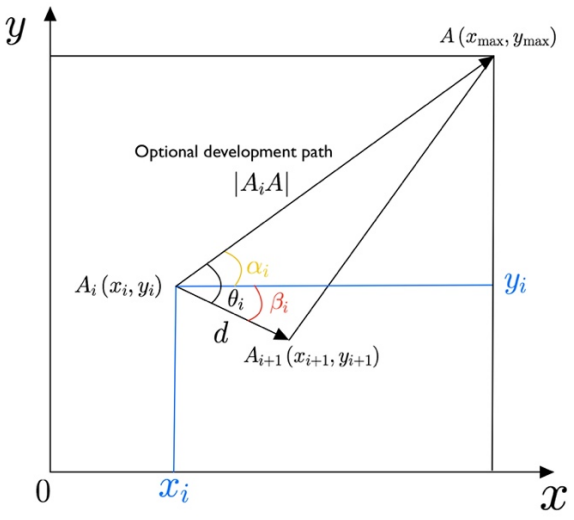

Figure 5 Controlled Development Model

Table 4: The meaning of the Parameter

Parameter	Meaning
x	DI
y	BI
A_i	Health State
θ_i	Influence Angle
$\overrightarrow{A_iA_{i+1}}$	Optimum Vector Direction
d	Deviation Distance
A	Expected Optimal Point

5.2.2 Controlled Development Trend

Before predicting the future developing trend, we must derive the solution for our model. The specific steps of the solution are presented below.

As shown in Figure 2, we define some important parameters. In order to determine the next point A_{i+1} after the implementation of the policies, we need to consider the relationships between the parameters x_i and x_{i+1}, y_i and y_{i+1}. According to the geometric relationship in the model, the relationship between them can be easily derived through the following formula:

$$x_{i+1} = x_i + d \cdot \cos\beta_i$$

$$y_{i+1} = y_i + d \cdot \sin\beta_i$$

$$where \quad \beta_i = \theta_i - \alpha_i \ , \ \alpha_i = \tan^{-1}\left(\frac{y_{max} - y_i}{x_{max} - x_i}\right) \ , \ d \ is \ a \ constant \ value$$

And θ_i can be derived through the following formula:

$$\theta_i = \alpha \cdot |A_iA| + \beta = -9.02|A_iA| + 5.209$$

$$where \quad |A_iA| = \sqrt{(x_{max} - x_i)^2 + (y_{max} - y_i)^2}$$

After deriving the recursive relationship, we can calculate the health level of the higher education system after 20 years, and we derive $A_n(x_n, y_n)$ by the following formula:

$$x_n = x_1 + \sum_{i=1}^{n} d \cdot \cos\beta_i$$

$$y_n = y_1 + \sum_{i=1}^{n} d \cdot \sin\beta_i$$

$$where \quad n = L/d = \frac{\gamma \cdot T}{d} = \frac{20 \cdot \gamma}{d}$$

Since d is controllable, we studied the effect the value of d has on the score of health state of HES after 20 years. The farther the distance, the lower the score. The specific results are shown in the following Figure 6.

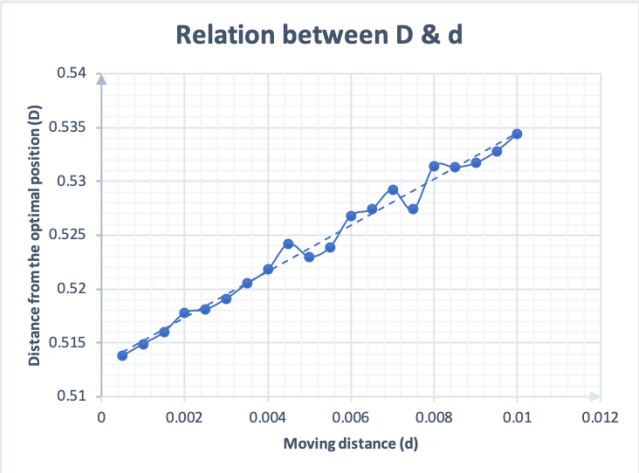

Figure 6 Relation between D & d

According to the figure above, we can observe that when d has a small value, the final health level of higher education is relatively high. Therefore, a conclusion can be drawn that when the deviation distance after each policies implementation is kept determined, a relatively moderate implementation will be more beneficial to the development of the US higher education system.

5.3 Analyses and Comparisons of the Two Modes

We fixed the value of d whereby we calculated the trend of the health of the US higher education system over the next 20 years and compared it with the natural trend. The results are shown below:

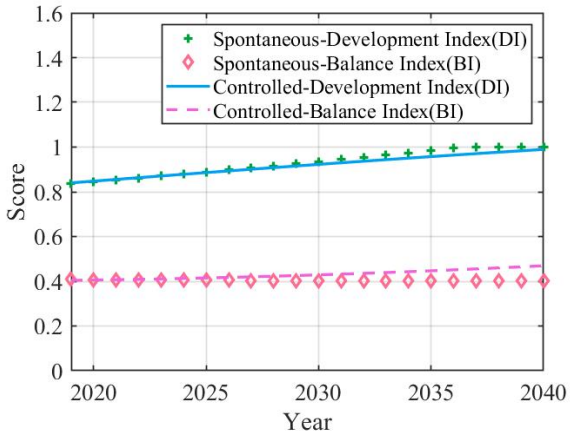

Figure 7 The each of index trend.

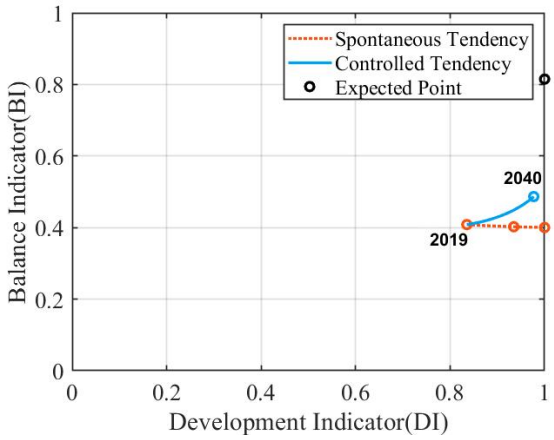

Figure 8 Trends in each development model

As can be seen from Figure 7 above, between the two development modes, BI is the one with a larger varying difference. Due to the already nearly satisfactory level of aspects measured by DI, the change of it after the policy intervention is not significant.

Next, in order to judge the effectiveness of the policies implemented, we define two indicators:

(1) φ which represents the ratio of the distance from the final position of the natural development mode to the proposed attainable and sustainable point and the distance from the final position of the controlled development mode to that expected point.

(2) ρ represents the percent change ratio of the final score under controllable development mode to that under natural development mode.

$$\varphi = \frac{0.415}{0.329} \approx 1.261 > 1$$

$$\rho = \frac{1.15 - 0.814}{0.814} = 41.3\%$$

When index φ is greater than 1, it is proved that the policy intervention in the controlled development mode is effective. Indicator ρ is the quantitative measurement of the improvement of the health level of the US higher education system. Based on the analyses above, we draw a conclusion that the policy implementation under government intervention does have a strong effectiveness.

6 Policies, Implementation Timeline & Real-world Impacts

In this section, we first proposed several appropriate targeted policies to migrate the current US HES into the proposed healthier and more sustainable state and then proposed the corresponding implementation timeline of those policies. Finally, we analyze the real-world impacts of the implementation of the policies.

6.1 Targeted Policies for Migration of US HES into a Healthier State

To migrate the current US HES into the ideal attainable and sustainable future, taking into account the advantages and disadvantages of it, utilizing our model, we propose the following policies concerning closely different aspects measured by DI and BI. Detailed policies are as follows.

To improve the aspects of US HES measured by DI, we have the following one-to-one targeted policies concerning every second-level indicator:

1. Increasing the financial and human resources inputs of HES
2. Increasing the share of higher educational public expenditure in government spending
3. Increasing the share of GERD in GDP
4. Improving the employment of higher education degree holders
5. Raising the wage rate of higher education degree holders

Similarly, to improve the aspects assessed by BI, we have another set of policies:

1. Providing freer academic environment and better treatment for higher education faculty
2. Encouraging more female to accept higher education
3. Supporting the research expenditure of research personnel

4. Strengthening the public recognition of higher education degree
5. Embracing international students
6. Supporting the scientific and technical research
7. Raising the wage rate of higher education faculty

6.2 Implementation Timeline of Targeted Policies

We make a short-term plan of 20 years for the policies to be implemented. Combined with our model, we deem that at the initial stage of the transition, all aspects of US HES concerned with DI and BI should be enhanced. In the mid-term and final stage of the transition, due to the initial nearly satisfactory state of aspects measured by DI and the steady growth resulting from the policies to be implemented, DI of US HES has already reached an ideal level. Accordingly, from then on, policies should focus on maintaining the aspects measured by DI while continue to reinforce the policies improving aspects represented by BI.

To give an intuition of our implementation timeline of our proposed policies, we draw the following bar chart measuring the supposed growth rate of BI and DI based on which we give the turning point of our targeted policies implementation.

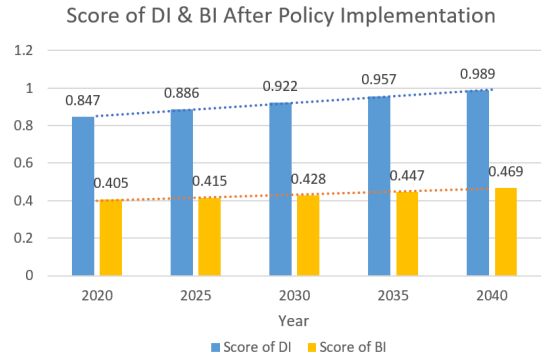

Figure 9 Score of DI & BI After Policy Implementation.

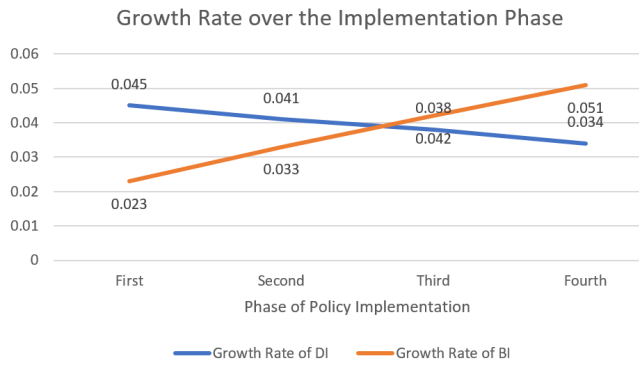

Figure 10. Growth Rate over the Implementation Phase

From the results above, we can see clearly that the crossing is between the second and the third phase, which is approximately the year 2030, thus we make the conclusion of our implementation timeline that from today to year 2030 we should focus on policies both improving the aspects concerned with the DI and BI and moreover, the strength on improving aspects relating to DI should be higher. After the year 2030, DI has come to a satisfactory outcome so from then on policies should mainly focus on improving the aspects concerned with BI to push the US HES to its final attainable and sustainable healthy state.

6.3 Real-world Impacts

The Real-world Impacts of Implementing Targeted Policies

Taking into account the fact that the efficacy of policies implemented may be hindered by real life factors such as the gap between what the federal government had planned and what the state government decided to act on. Therefore, it is important to discuss the real-world impact of our targeted policies to be implemented, acknowledging the fact that change is hard. We divide the impacts into two stages, the transition stage and the final stage. We analyze the impacts from two angles, which are micro view involving students, faculty and schools and macro one from the nation as a whole.

Micro view

- To students, the targeted policies are to lower the ratio between students and teachers in higher education institutions and to increase the amount of expenditure and human resources as well measured in dollar terms invested in a common higher education accepter. During the transition phase, this will render students in higher education institutions a better studying experience since the loans or financial burdens for them will decrease and that they would get better guidance due to the proportional increase of teaching staffs. At the end stage, students will have an easier access to higher education of high quality.

- To faculty, the targeted policies are to increase the number of them, which may involve the efforts of increasing the salary or treatment of higher education teaching staffs to appeal more people into the job market of higher education institutions. We use Supply and Demand model to analyze the impacts of the policies concerned. In the transition stage, there will be a larger demand of higher education faculty which can be represented by a rightward shift of the demand curve in the job market for higher education. This will raise the wage rate of higher education faculty and therefore yield to a rightward shift of the supply curve as well, which contributes to the growth of number of higher education faculty. However, in the end state, although the number of higher education faculty does rise for both the supply curve and demand curve shift rightwards, the change to the wage rate is ambiguous, so in the end state there isn't necessarily a result that more faculty will be in the higher education system.

- To schools, the targeted policies are to increase the proportion of international students and lower the tuition fees of students in an effort to embrace more brilliant minds from all over the world and provide opportunities to those who have the ability and intention to accept higher education but cannot afford to do so. In the transition stage, schools must balance the enrollment rate of national and international students for the total number of students it can take up is set. Besides, lowering tuition fees means a loss of school's income, in order to maintain the basic revenue level, the school must adjust its income structure. In the meantime, the government must lend a helping hand to higher education institutions in the migration by increasing government spending on higher education institutions. In the end state, the schools will depend more on government transfers and social donations and have a higher proportion of international students.

Macro view

- To the nation as a whole, during the transition stage, the policies to be implemented will heavier the burden of government budget for it should strive for a higher salary for higher education staffs, a lower tuition fee for students and a larger amount spent on research and development. Moreover, the nation will face a higher level of security problem for there will be more international students pouring into it. However, in the end state of the transformation, the nation will have a healthier, more international and open HES.

7 Sensitivity Analysis

In order to investigate the influence of the changes in various indicators on the health level of higher education system under the spontaneous development trend, we need to conduct sensitivity analysis on the Development Indicators (DI) and Balance Indicators (BI). *We refer to the magnitude of the influence degree as the sensitivity coefficient of the attribute. The greater the sensitivity coefficient, the greater the influence of this attribute on the model output*.[8]

We controlled the rate of the change in Development Indicators (DI) and Balance Indicators (BI), which were set at 1%, 2% and 5% respectively, and then analyzed the impact of these changes at different years on the health of the higher education system under the natural pattern of development. The specific results are shown in the Figure 11 and 12 below:

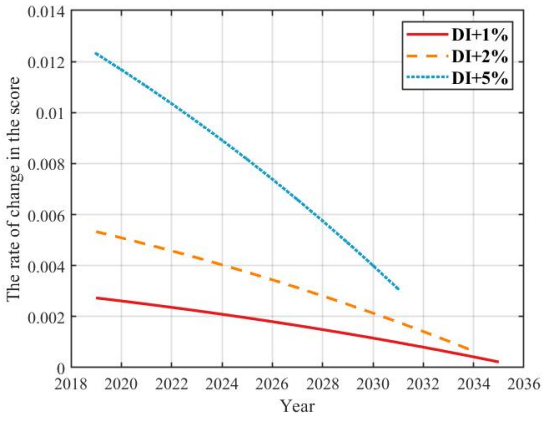

Figure 11 Sensitivity of DI in different years

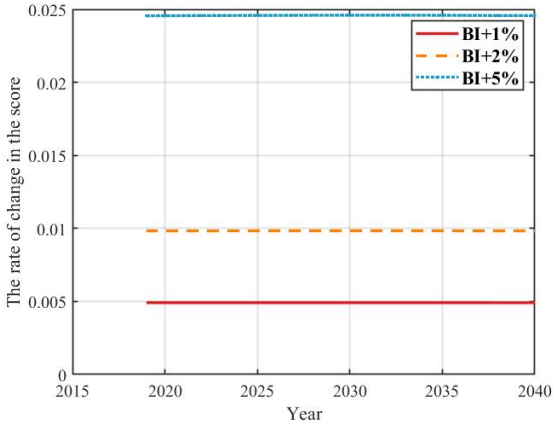

Figure 12 Sensitivity of BI in different years

According to the results in the figure above, we can know that the sensitivity coefficient of DI shows a decreasing trend with the year elapsed. The sensitivity coefficient of BI was almost constant with the year elapsed, and the sensitivity coefficient of BI was larger than that of DI on the whole. Therefore, the US higher education system should focus on DI and BI at the initial

stage of development, and BI in the final stage. This is also a strong confirmation that the policy interventions we have proposed before are in the right track.

Strength & Weakness | 8

8.1 Strengths

Systematic

Our model is systematic by its nature. We first build a system of Health Indicators for Higher Education System, which contains two first-level indicators DI and BI and each of them also contains several second-level indicators to make for a hierarchical and all-round assessing measurement of a nation's higher education system. Our modified GE-Matrix enables us to first score the health state of a nation's higher education system and based on the score we can subsequently propose a series of policies to be implemented.

Quantifiable

Our model innovatively presents a quantitative measurement of the health state of any nation's higher education system by using the modified GE-Matrix. Particularly. Our model also enables us to give a quantitative judgement of the efficiency of the policies implemented. Specifically, we deem our policies on the US HES have a 41.3% improvement.

Interdisciplinary

We integrate disciplinary knowledge from different fields such as business and economics into our models and the subsequent discussions of the real-world effects of our policies. Our assessing model originates from the GE-Matrix established by General Electric in the last century. We use the laws of supply and demand in the last section of discussing the real-world impact of our proposed policies.

8.2 Weaknesses

We establish our modified GE-Matrix assessing the health of a nation's higher education system based on quantifiable indicators from different perspectives. It would be better if we could collect more data from a broader range whereby providing a more all-round assessment system.

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