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Research on the Health level of higher Education based on the quantification of Entropy weight Index system

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Abstract: *The diversity in higher education system calls for a reliable way to evaluate the health and sustainability of those systems. First of all, this paper quantifies the indicators to evaluate the health of the higher education system from three different dimensions: equity, resource access and cost-effectiveness. For the equity dimension, we designed public/private equity scores, gender equity scores and registration levels to capture different aspects of unfairness. At the same time, we use the entropy method to set the weight for each index and generate the weighted average score and equity score. In addition, we design the Wealth Equity Index (WEI) as a supplementary index. For the dimension of resource access, we use per capita accessibility index to capture the richness of higher education resources. For the cost-effective dimension, we first use a fixed-effect model to test the correlation between "output" and "input". Then we designed the average higher education output to weigh the benefits of higher education.*

Keywords: *Higher education system, Entropy weight method, equity, Index quantification*

1. Introduction

The system of higher education plays a non-replaceable role in the long-term development of a country. It also contributes to the foundation of the boost of the economic growth. Since the late 20th century, the expansion of higher education has become the trend [1]. Take China as an example, the enrollment rate of tertiary education has climbed from 1.55% in 1978 to 51.6% in 2019. The universalization of higher education ensures the current and future competitiveness of a country. With the rapid evolution of higher education system, the concept of a more healthy and sustainable higher education system has been put forward [2]. The UNESCO has been establishing close cooperation with the governments, IGOs, NGOs, institutions and universities from the world to guarantee the healthy and sustainable development of the higher education system.

2. Data Normalization

All of the indicators in the model are divided into positive indicators and negative indicators. For positive indicators, the bigger original value is better. Oppositely, for negative indicators, the smaller original value is better. Assume that n countries and m indicators are included in this model [3]. In following equations, x_{ij} represents the actual value of indicator j (both positive and negative) for sample country i, where (i = 1,2, , n)and (j = 1,2, , m). X_{ij} is the index after normalization. For positive indicators, we have:

$$X_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_j - \min x_j} \tag{1}$$

For negative indicators, following equation is obtained:

$$X_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j} \tag{2}$$

For negative indicators, following equation is obtained:

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3. Quality Model of higher Education system based on Entropy method

The Equity Index contains 3 indicators. Public/Private Equity Score is based on the ratio of public universities student-teacher ratio to private college student-teacher ratio. The ratio is a negative indicator because the bigger the ratio [4], the difference of the student-teacher ratio is more obvious (OEC). Enrollment level score is based on the enrollment rate of tertiary education after secondary school [5] [6]. Gender equity score is calculated from the data of Female-Male ratio.

Calculate the weight of each indicator, the proportion is listed below:

$$y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \left(0 \le X_{ij} \le 1\right) \tag{3}$$

Then the Indicator Data Matrix is done. It is composed of n countries and m indicators. Here is the original matrix:

$$Y = \left\{ y_{ij} \right\}_{n \times m} \tag{4}$$

Get the comentropy of indicator j (wenku):

$$e_j = -K \sum_{i=1}^{n} y_{ij} \ln y_{ij}, \left(\text{K is constant}, \ \text{K} = \frac{1}{\ln n} \right) \tag{5}$$

The value of information content depends on the difference between the comentropy of that indicator and 1 and the difference will determine the weight directly. We get the difference:

$$d_j = 1 - e_j \tag{6}$$

The essence of Entropy Estimate is to calculate the value of information content of each indicator and that value will be reflected in the weight. Therefore, the weight equation is worked out:

$$w_j = \frac{d_j}{\sum_{i=1}^{n} d_j} \tag{7}$$

With that weight, we can calculate the score of each indicator and then get the comprehensive rating. The score is obtained by calculating the weighed sum:

$$S = \sum_{i=1}^{m} y_{ij} w_j \tag{8}$$

From the figures we can conclude that the united States get high score in enrollment level and undoubtedly ranks 1st. But out of expectation, the countries in Northern Europe are among the lowest ranking countries. This is probably because the extremely big variance of enrollment rate (average rate: United States 37.9%, 2013-2018; Finland 8.6%, 2013-2018) increases its weight in the model when using Entropy Method. The conventional education choice of a nation leads to that big variance to a great extent.

But if focus on the Public/Private Equity score, we will find that United States is second from bottom, which means that in the perspective of wealth equity, the USA higher education system has to take actions to narrow the gap between the public and the private colleges. To further examine that kind of inequity of American higher education system, we build another model.

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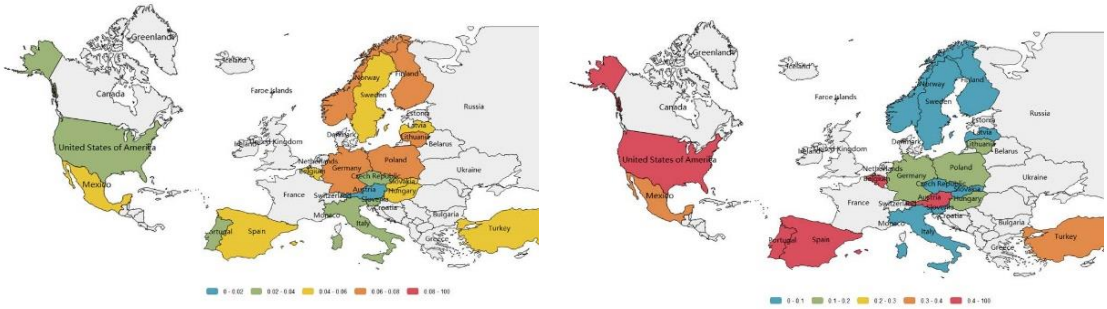
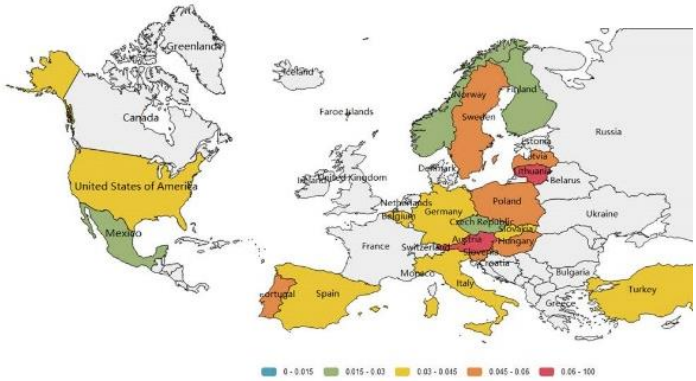


(a) Public/Private Equity Score (b) Enrollment Level Score



(c) Gender Equity Score

Figure 1: 3 Scores

4. Further Discussion of higher Education system

The difference between the Enrollment Level Score listed above may attribute to the macro level such as national policy. But it doesn't take the wealth inequity into consideration. Only 1 indicator (Public/Private Student-Teacher Ratio) in the model is associated with the wealth inequity. But actually, it is a vital indicator for the equity of education system. Therefore, we develop a new Index, Wealth Equity Index to measure how the difference of wealth background influence the access to higher education:

$$WEI = \frac{E_{\text{middle}} - E_{\text{poor}}}{E_{\text{rich}} - E_{\text{poor}}} \tag{9}$$

In the formula: Emiddlerepresents the percentage of median-wealth-group people aged 25 to 29, who have completed at least four years of higher education.

Epoor represents the percentage of poor-wealth-group people aged 25to 29, who have completed at least four years of higher education.

Erich represents the percentage of rich-wealth-group people aged 25to 29, who have completed at least four years of higher education.

Note: UNESCO divide wealth into 5 levels: poorest, poor, middle, rich, richest(rat).

We apply this model to United States and other 4 developing countries, including China, Colombia, Brazil and Costa Rica. The visualization of Education-Completing rate of different wealth-group is obtained:

(a) United States, 2013 (b) United States, 2016

Figure 2: The USA

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(a) Costa Rica, 2011 (b) Costa Rica, 2018

Figure 3: Costa Rica

(a) Brazil, 2011 (b) Brazil, 2012

(c) Brazil, 2013 (d) Brazil, 2011

Figure 4: Brazil

(a) Colombia, 2010 (b) Colombia, 2015

Figure 5: Colombia

The line chart of WEI of 4 countries are listed below:

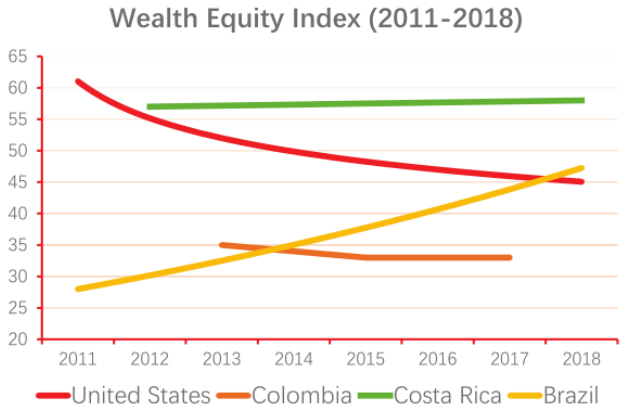

Figure 6: Wealth Equality Index (2011-2018)

From the visualization picture and the line chart, we can see that even in Brazil, a country with striking gap of wealth, the trend of WEI is climbing up. But the WEI of United States is on the way going down. The result of the WEI combined with the Public/Private Equity Score means that the Wealth/Class Equity of the higher education system in United States has room for improvement. Unless measures are taken in time, the situation will get worse.

5. Education Resource

To test the higher education resource of a country, we define an index of educational resources available per student:

$$\frac{H-index}{\text{student-teacher ratio}} \tag{10}$$

Faculty resources are applied to quantify the level of educational resources available per student in this index. First, in this index, the student-teacher ratio are used to measure the number of students per teacher; the smaller the student-teacher ratio is, the more abundant the teacher resources are. However, it only reflects the adequacy of teachers rather than their ability and proficiency. This paper thus uses a country's Hindex to measure the overall research level of a country to represent the quality of teachers. Second, the H-index or Hirsch index measures the scientific output of a single researcher as a single-number standard combining both quantity and quality of publications (3). The h-index is defined as "A

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scientist has index h if h of his or her N papers have at least h citations each and the other (N-h) papers have fewer than h citations each"(5). The H-index is stable with year and is objective to reflect a country's research level.

Higher H-index might be a result of a large number of faculty in tertiary institutions, however, abundant faculty is an advantage itself, and research output is a public good, a resource that can spill over. The H-index in national level thus can measure overall research levels to capture the quality of faculty. Dividing the H-index by the student-teacher ratio, it can be obtained an index reflecting the availability of educational resources per capita. It reflects both the abundance and the quality of teachers.

6. Conclusion

This paper models and analyzes the health of the higher education system. For the dimension of equity, this paper designs the public / private equity score, gender equity score and registration level, in order to capture different aspects of unfairness. Then the entropy method is used to set the weight to generate the weighted average score and equity score. Then the per capita accessibility index is used to capture the richness of higher education resources. For the cost-effective dimension, we first use a fixed-effect model to test the correlation between "output" and "input". Then the paper designed the average higher education output to weigh the benefits of higher education.

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