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Analysis on the Sustainable Development of Higher Education Based on Rank-Sum Ratio and Time Series

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Abstract: In order to help every country to have a healthy and sustainable higher education system, this paper proposes a series of mathematical models, including Rank-Sum Ratio Model and Time Series Model to measure and assess the health of higher education system at a national level, and identify a healthy and sustainable state of higher education system and propose and analyze relevant effective policies for one country. After collecting various valid education-related data, a Rank-Sum Ratio Model is used to analyze and rank the current comprehensive education strength of the U.S.and Japan. According to the raking result, we further choose three countries, including the United States, Japan and China, for specific analysis.A Time Series Model is used to predict the missing higher education data in 2020 for the United States, Japan and China, as the data of 2020 have not been published.

1. Introduction

The higher education system is an important part of a country. It further provides elementary and secondary education for its citizens beyond compulsory education. Different countries have various methods of higher education, and there are many countries that attract a large number of international students every year, such as the United States, the United Kingdom, and Australia. However, the higher education systems of these countries have their advantages and disadvantages. Therefore, effective adjustments are necessary, but it is also difficult to implement these policies over a long period and achieve a healthy and sustainable system.

According to the current situation, a model needs to be developed to measure and evaluate the health of higher education system at national level, a healthy and sustainable state of a targeted country's higher education system has to be identified, and a set of policies have to be proposed and analyzed to make the targeted country develop into the expected healthy sustainable state.

2. Rank-Sum Ratio Model

Rank-Sum Ratio (RSR) is a comprehensive evaluation method developed by Tian Fengdiao [1]. This method uses rank transformation to calculate dimensionless statistical index (RSR) from matrix. Then the parameter statistical method can be used to explore the distribution of RSR. Generally, the RSR indicator ranges from zero (worst) to one (best), and follows a normal distribution. In addition, the RSR sequence or a set of sequence classifications can be used to assess the state of the subject (worst/best) [2].

The RSR rank sum ratio method requires a total of five steps, which are RSR value calculation, RSR distribution calculation, model fitting, critical value classification and result classification.

(1) Create an $m \times n$ matrix (see Table 1): n represents the number of variables, and m represents the number of subjects. Set high-quality (if any) and low-quality indicators (if any).

Table 1: Data for five countries in 2019

	ER	PTR	GER	NI	SR Top10	CR Top50
U.S.	91.90%	13.8	86.30%	4213	284	30
Japan	98.50%	15.43	63.46%	782	3	0
China	91.50%	17.95	51.60%	2688	84	1
Australia	78.70%	21.83	101.60%	40	20	3
U.K.	87.50%	16.23	61.20%	143	54	6

(2) Perform RSR distribution table calculation (see Table 2). Obtain the RSR distribution value. Get the Probit value.

Table 2: RSR distribution table

RSR	f	Σf	average rank	average rank /n*100%	Probit
0.3667	1	1	1.0	20.0	4.158
0.5333	1	2	2.0	40.0	4.747
0.6000	1	3	3.0	60.0	5.253
0.6667	1	4	4.0	80.0	5.842
0.8333	1	5	5.0	95.0	6.645

Note：The grey table is estimated by (1-1/4* N)

(3) Use the RSR distribution value as the independent variable and the Probit value as the dependent variable to perform linear regression. Get $F(1,3) = 124.827, p = 0.002$.

(4) Get the sorting thresholds table (see Table 3).

Table 3: Sorting thresholds table

Level	Percentile Threshold	Probit Threshold	RSR Fitted Value
1	< 15.866	< 4	< 0.366
2	15.866 ~	4 ~	0.366 ~
3	84.134 ~	6 ~	0.718 ~

(5) Perform interval comparisons through the RSR fitted value and the RSR critical (fitted value) to obtain the Level (see Table 4). The higher the Level, the healthier the higher education system.

Table 4: RSR Level table

	RSR	RSR rank	RSR Fitted Value	Level
1	0.600	3	0.587	2
2	0.367	5	0.394	2
3	0.533	4	0.497	2
4	0.833	1	0.832	3
5	0.667	2	0.690	2

(6) Get the RSR result (see Table 5). The result is that Australia ranked first, the United Kingdom second, the United States third, China fourth, and Japan fifth.

Table 5: RSR result table

	ER	NI	PTR	GER	SR_{TOP10}	CR_{TOP50}	RSR	RSR rank
1	2.0	1.0	1.0	4.0	5.0	5.0	0.600	3
2	1.0	3.0	2.0	3.0	1.0	1.0	0.367	5
3	3.0	2.0	4.0	1.0	4.0	2.0	0.533	4
4	5.0	5.0	5.0	5.0	2.0	3.0	0.833	1
5	4.0	4.0	3.0	2.0	3.0	4.0	0.667	2

The advantages of Rank-Sum Ratio include: (a) It is easy to use and does not require other data. (b) It is flexible and can be used in combination with other statistical methods. (c) It is useful for comparing differences or finding correlations.

3. Time Series Model

Time series analysis refers to the theory and method of establishing mathematical models through curve fitting and parameter estimation based on the time series data obtained from systematic observations [2]. The main purpose of time series analysis is to predict the future based on existing historical data [3]. Based on such time series, by using relevant time series model, we can theoretically predict the health of different nations' system of higher education in the future though fitting and regression of historical data. However, the sequence of different nations' system of higher education needs to be treated differently.

(1) Number of Higher Education Institutions in America: After analyzing the data about America, we find that because of the special situation of the decrease of international students in the United States in recent years, the number of higher education institutions has decreased, but it will not continue to decrease. Additionally, many factors can affect the number of universities, including economic conditions. Therefore, the forecast of this data by the time series model is not accurate.

(2) Subject Rankings and University Rankings. There are many factors affecting subject rankings and university rankings in each country, and there remains great uncertainty. Take the United States as an example (see Figure 1), the forecast results from the time series model for subject ranking are unreasonable. Therefore, no prediction will be made on subject rankings and university rankings.

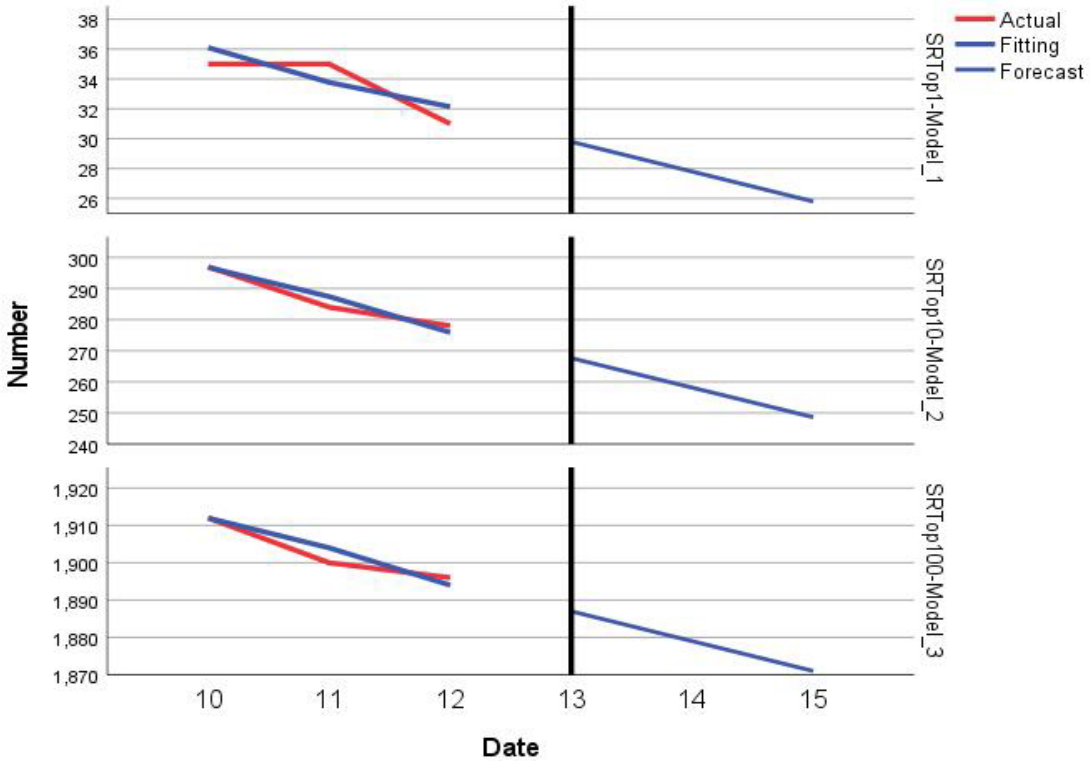

Figure 1: Prediction of American subject rankings and university rankings

(3) Employment rate in some country. The employment rate in some countries increases every year, but it will stabilize and will not exceed 100%. Take Japan (see Figure 2) as an example, the prediction of ER_{Japan} by time series model exceed 100% in three years, which is impossible. Therefore, the future employment rate prediction is only accurate in one or two years.

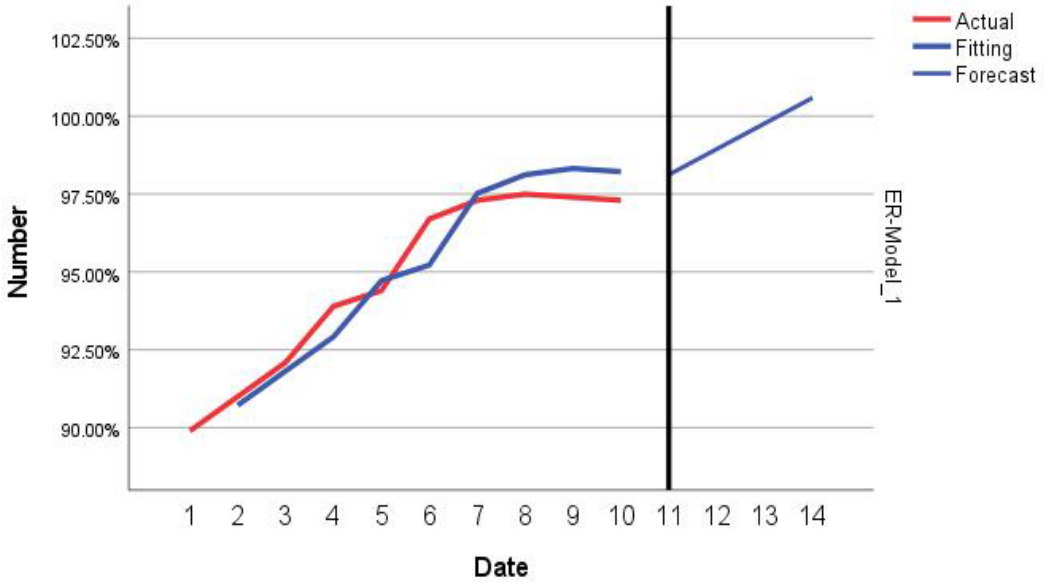

Figure 2: Employment forecast for Japan

4. Conclusion

In conclusion, this paper manages to use a series of mathematical models, including Rank-Sum Ratio Model, Time Series Model, BP Neural Network Model and Factor Analysis Model to measure and assess the health of higher education system at a national level. We apply the model to five representative countries. Firstly, we use Rank-Sum Ratio Model to analyze and rank the current comprehensive education strength of these five countries. According to the ranking result, we choose United States, Japan and China for further analysis as they take the bottom three. Secondly, we use Time Series Model to predict the missing higher education data in 2020 of the United States and Japan.

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