

A Multi-dimensional Evaluation Model for Higher Education

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Abstract

The UN interprets the meaning of sustainable education as qualified education should be provided with affordable and accessible facilities regardless of gender or disabilities; besides, learners can acquire the knowledge to enhance sustainability with the help of qualified teachers. However, as a complicated system, it is difficult to measure and evaluate the health status of a sustainable higher education system. In this paper, we establish a multi-dimensional model to evaluate the health status of higher education system at the national level. The goals of our model are three-fold: comprehensiveness, simplicity to implement; and data availability. Firstly, we propose a five-dimensional indicator system which includes Accessibility, Affordability, Edification, Equity and Internationalization, and find corresponding indicators and data from World Bank. Then we adopt EWM-TPOSIS method to weight and aggregate all the indicators into a final score representing the health status of a nation. Secondly, we implement the above method to 12 countries, and the resulted score ranking from highest to lowest are Russia, Portugal, Spain, Switzerland, Ireland, Belgium, Canada, Czech Republic, Cyprus, Italy, Mexico, Columbia. We also test the sensibility of our method with Factor Analysis. The two rankings are quite different except for the top and bottom countries. It can happen because Factor Analysis eliminates some information by using principal component method. We perform a KMO and Bartlett's Test, which indicates that the indicators in our data do not have strong enough correlations, so that Factor Analysis is not the best method in this scenario, which in a way validates the EWM - TPOSIS method that we adopt. Thirdly, by comparing the health score and economic development level (measured by GDP per capita), we notice that Italy is a country whose education system has room of improvements. Specifically, we identify two important areas with the necessity to improve, which are relative low higher education enrollment rate and graduation rate. We propose a targeted vision for Italy, and suggest policies towards that vision. With a time-series analysis, we also suggest a timeline for the proposed change. Finally, we acknowledge the difficulties of change in the real world, especially with the strong impact of the current pandemic on Italy. One limitation of our analysis, given the time restraint, is that we couldn't find data of a few indicators that we would like to include in our evaluation system. To name a couple, the research level of a higher education system or the average salary level of a college graduate in a nation. By integrating more of these indicators, our evaluation system would yield more satisfactory results.

Keywords

Higher education; Sustainable system; World Bank; EWM - TPOSIS; Factor Analysis; Italy; time-series analysis.

1. Introduction

1.1. Background

Over the past few decades, higher education has developed as a worldwide trend, and this trend is expected to continue. Nowadays, higher education has been widely accepted and become an important channel to promote economic and social development. Higher education has been widely accepted and become an important channel to promote economic and social development. The fact that some countries have enjoyed the benefits of higher education in terms of economy, social welfare and human resources after launching strategies and programs aimed at enhancing the competitiveness of higher education is just another testament to the importance of higher education and reinforces the continued focus on it.

However, regional and factorial imbalances still exist in the higher education system of each country. How to measure and evaluate the health condition of a nation's higher education system becomes an important research question. It is also the correct starting point of any sensible policy aiming at enhancing the competitiveness of higher education.

In this background, the purpose of this paper is to solve the following research questions.

1.2. Restatement of the Tasks

Task 1 Develop and validate an evaluation model that can assess the health status of any country's higher education system

Task 2 The established model is applied to several different countries, and according to the analysis, a country whose higher education system needs to be improved is selected.

Task 3 Propose an achievable and reasonable proposal for the higher education system in the chosen country to support a healthy and sustainable higher education system.

Task 4 Analyze the health status of the higher education system in the selected country, and put forward the corresponding healthy and sustainable development plan.

Task 5 Implement reasonable step planning according to the current and expected development characteristics of the countries studied, and support migration from the current state to the ideal state through the arrangement of implementation schedules

Task 6 Discuss the realistic impact of implementing your plan during the interim and final stages on national indicators.

2. Notations

Table 1. Notations

Symbol	Representation
P_{ij}	The weight of an index of a country in the sum of all the indicators
j^{th}	The figures of country in each indicators
i^{th}	The figures of indicators in each country
V_{ij}	The single index we selected to reflect the corresponding indicators
E	The information entropy of indicators is obtained after calculation
w_j	The weight of indicators after using EWM algorithm
M	The largest data in the current indicator
L	The smallest data in the current indicator
S_i^+	The distance between the current country and the best country
S_i^-	The distance between the current country and the worst country
$score_i$	The calculated relative score of the current country in all countries

3. Multi-dimensional Evaluation Model

3.1. Overall Analysis

Higher education system is complex and complicated, so is the task of measuring the health of it. From current literature, there are two types of approaches to evaluate sustainable higher education: qualitative and quantitative. Qualitative approaches are mostly used to explain the origin and development of sustainable higher education and quantitative approaches are mostly used to explore the contributions of each influencing factor to a sustainable higher education.

Our goal here is to establish a quantitative evaluation model at national level which has the following features: (1) comprehensive; (2) easy to implement; and (3) data are currently available internationally. According to the above three criteria, we first develop a multi-dimensional indicator system, and then use weighting and aggregation method to rank the health status of all nations.

The commonly used weighting and aggregation methods are also divided into subjective approaches and objective approaches. Subjective approaches such as Delphi method and Hierarchy Process Analysis use professional opinions to obtain weights of each indicator. Objective approaches include cluster analysis, grey correlation analysis, Entropy Weight Method (EWM), and technique for order preference by similarity to an ideal solution (TOPSIS) and factor analysis. We prefer objective approaches that are based on the data and guarantees the objectivity of the evaluation results.

It is also documented that cluster analysis and grey correlation analysis are likely to have less satisfactory performances if they are used solely without combining other methods. Therefore, we decide to use the combination of EWM-TOPSIS method with a sensibility test using factor analysis.

3.2. System of Multi-dimensional Indicators

The UN interprets the meaning of sustainable education as qualified education should be provided with affordable and accessible facilities regardless of gender or disabilities; besides, learners can acquire the knowledge to enhance sustainability with the help of qualified teachers. Based on the definition of sustainable education system, we propose a five-dimensional evolution system: Accessibility, Affordability, Edification, Equity and Internationalization.

Accessibility refers to the scope of higher education in a nation, or the extent to which of people from all backgrounds can access and benefit from higher education.

Affordability captures the cost of higher education in relation to the financial means and support students receive.

Edification refers to the quality of higher education. It can be reflected by teaching and research outcome of a higher education system.

Equality refers to equal opportunities for women or disadvantaged people group to participate in higher education activities.

Internationalization refers to the equal opportunity of international participants to participate in higher education and the interaction that embodies inclusive social values.

All above dimensions can be measured with various indicators. We choose indicators out of the consideration of data availability and comparability. We prefer data source which give the same calibration across all nations. After weighting on the quality of data from different data sources, we decide to adopt databank from World Bank. The indicators for each of the five dimensions from World Bank databank are listed in the table below.

Table 2. Five-dimensional Evaluation System and Corresponding Indicators

Accessibility	Gross enrolment ratio for tertiary education, both sexes (%)
Affordability	Initial government funding per tertiary student as a percentage of GDP per capita Initial household funding per tertiary student as a percentage of GDP per capita
Edification	Teachers in tertiary education programmes, both sexes (number)/Enrolment in tertiary education, all programmes, both sexes (number) Teaching staff compensation as a percentage of total expenditure in tertiary public institutions (%) Gross graduation ratio from first degree programmes (ISCED 6 and 7) in tertiary education, both sexes (%)
Equality	Enrolment in tertiary education, all programmes, female (number) /Enrolment in tertiary education, all programmes, both sexes (number)
Internationalization	Total inbound internationally mobile students, both sexes (number) /Enrolment in tertiary education, all programmes, both sexes (number)

3.3. Entropy Weights Calculation

Entropy weight method, as an objective weighting method, determines the weight of each index according to the information provided by each index data.

First, we calculate the proportion P_{ij} of the j^{th} indicator of the i^{th} country.

$$P_{ij} = \frac{V_{ij}}{\sum_{i=1}^n V_{ij}}$$

i represents the ordinal number of the countries.

j represents the ordinal number of the indicators.

V_{ij} means the value of the corresponding indicator.

n represents the number of the countries

Then we get the Entropy Value E of the j^{th} indicator as below.

$$E_j = -\ln n \sum_{i=1}^n (p_{ij} \times \ln p_{ij})$$

So that we can get the weight W_j of the j^{th} indicator.

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

where m is the number of the indicators.

3.4. TOPSIS Evaluation

TOPSIS is an effective method to rank alternatives, which has been widely used in various fields. By using TOPSIS, we can obtain the shortest distances of alternatives from the most preferred

alternatives and the longest distances of alternatives from the least preferred alternatives. The procedures are as follows.

First, we calculate the most preferred alternative M and the least preferred alternative L :

$$M = (\max V_{i1}, \max V_{i2}, \dots, \max V_{im}),$$

$$L = (\min V_{i1}, \min V_{i2}, \dots, \min V_{im}).$$

Then we calculate separation degree S :

$$S_i^+ = \sqrt{\sum_{j=1}^m W_j (V_{ij} - M_j)^2},$$

$$S_i^- = \sqrt{\sum_{j=1}^m W_j (V_{ij} - L_j)^2}.$$

Finally, we calculate the development degree of integration of higher education in the ideal situation. $score_i$ reflects the relative closeness to the preferred alternative, and the higher value of $score_i$ represents the better development status of higher education in the region.

$$score_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

The values of $score_i$ fluctuate between 0 and 1, and it represents the health condition of a country's higher education system. Based on this score, all countries can be ranked as well.

4. Evaluation Results on 12 Countries

We implement the above proposed EWM-TOPSIS model to 12 countries: Belgium, Canada, Columbia, Cyprus, Czech Republic, Ireland, Italy, Mexico, Portugal, Russia, Spain, and Switzerland. The data of the 12 countries can be viewed in Appendix 1.

4.1. EWM-TOPSIS Results

The final rankings of 12 countries are listed in the table below.

Table 3. Higher Education Health Ranking of 12 Countries (EWM_TOPSIS Method)

Country	Ranking	Score
Russian Federation	1	0.7375
Portugal	2	0.6013
Spain	3	0.5991
Switzerland	4	0.4981
Ireland	5	0.4832
Belgium	6	0.4826
Canada*	7	0.4092
Czech Republic	8	0.4059
Cyprus	9	0.3789
Italy	10	0.3239
Mexico	11	0.2598
Colombia	12	0.2503

*Canada has a missing data in one of the indicators and the data was supplemented by data in previous year.

As we can see, a two-tiered-group can be spotted: the first tier with a score slightly above or close to 0.5 with the countries of Russia, Portugal, Spain, Switzerland, Ireland and Belgium, and the second tier with a score below 0.5 with the countries of Canada, Czech Republic, Cyprus, Italy, Mexico and Colombia, While Russia stands out as the top ranked country and Mexico and Colombia are significantly lower than the rest of the countries.

We also noticed that Italy ranked pretty low among the 12 countries, only outperforming the two developing countries Mexico and Colombia. We will examine the performance of Italy more closely in Section 5.

4.2. Sensitivity Analysis with Factor Analysis

Factor Analysis is also a frequently used method in evaluation studies. So we also performed a Factor Analysis using SPSS as a sensitivity analysis. The variance explained by the initial eight indicators as listed in the table below.

Table 4. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.417	30.210	30.210	2.417	30.210	30.210	2.172	27.155	27.155
2	1.942	24.275	54.484	1.942	24.275	54.484	1.778	22.228	49.383
3	1.591	19.891	74.376	1.591	19.891	74.376	1.453	18.164	67.547
4	.720	8.997	83.372	.720	8.997	83.372	1.266	15.826	83.372
5	.585	7.315	90.688						
6	.399	4.989	95.677						
7	.296	3.700	99.377						
8	.050	.623	100.000						

By the criteria of preserving component which can cumulatively explain above 80% of the total variance, we decide to take four components. We also rotate the components to obtain meaningful interpretation of the components. The resulted rotated component matrix is list below.

Table 5. Rotated Component Matrix

	Component			
	1	2	3	4
Teache_student_ratio	.883	.227	.104	.235
Teacher_compesation	.562	.164	-.629	-.188
Female_student_ratio	-.724	.170	.156	-.057
Gross_enrollment_ratio	-.254	.784	.278	-.245
Government_funding	.254	-.113	.298	.862
Household_funding	-.544	.562	.069	.565
Inbound_student_ratio	.030	.129	.906	.187
Graduate_rate	.357	.843	-.172	.117

As seen from Table 5, the first component is high on the coefficients of Teacher_student_ratio and Teacher_compensation, so it can be named Edification factor. The second component is

high on the coefficients of Graduate_rate and Gross_enrollment ratio, while Graduate_rate is used to measure the teaching outcome which is Edification factor, but here when combined with Gross_enrollment ratio, we can lossly name the combined component Accessibility component. The third component is high on the coefficient of inbound_student_ratio, so it can be named Internationalization component, and the fourth one is high on the coefficient of Government_funding, which can be named as Affordability component. As we can see, by performing Factor Analysis, we lose some information, namely Equity.

By using the proportion of each component in explaining the total variances as weights, we can calculate a total score for each of the countries, namely

$$score_i = \sum_{j=1}^m v_j / V \times F_{ij}$$

i represents the ordinal number of the 12 countries.

j represents the ordinal number of the components.

v_j means the proportion of each component in explaining the total variances

V represents the total of the variances

The resulted ranking is listed below.

Table 6. Higher Education Health Ranking of 12 Countries (Factor Analysis)

Country	Ranking
Switzerland	1
Russian Federation	2
Canada	3
Cyprus	4
Portugal	5
Spain	6
Ireland	7
Belgium	8
Mexico	9
Czech Republic	10
Italy	11
Colombia	12

The ranking is quite different from the one using EWM-TOPSIS method, except for the upper and bottom countries; it is not surprising in that Factor Analysis automatically eliminates information by principal component methods. We further performed a KMO and Bartlett's Test, which is usually used to validate the use of factor analysis method. The result is listed below. The usual requirement for Kaiser-Olkin measure is above 0.8, while in our data it is only 0.351. Therefore, in our particular case, Factor Analysis is not the best evaluation method, which in a way reinforces the legitimacy of using EWM-TOPSIS model.

Table 7. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.351
	Approx. Chi-Square	29.912
Bartlett's Test of Sphericity	df	28
	Sig.	.367

5. Improvements for Italy

5.1. Identify Areas of Improvements

In the model, Italy scores poorly overall. From the point of view of national GDP per capita, Italy's GDP per capita is relatively high, yet five countries with lower GDP per capita all outperform Italy. This shows that there exists room of improvements for Italy's higher education system.

Table 8. GDP per capita Comparison of the 12 Countries

Country	GDP per capita (current US\$)						
	2012	2013	2014	2015	2016	2017	2018
Russian Federation	15434.57	16007.09	14100.73	9313.79	8745.38	10750.59	11288.88
Portugal	20564.89	21647.04	22074.30	19242.37	19978.40	21437.35	23407.91
Spain	28324.43	29059.55	29461.55	25732.02	26505.62	28100.85	30370.89
Switzerland	83538.21	85112.47	86605.52	82081.61	80172.19	80450.05	82796.55
Ireland	48917.90	51590.19	55492.98	61995.42	63197.08	69649.88	78806.43
Belgium	44673.12	46744.66	47700.54	40991.81	42012.10	44219.56	47518.64
Canada	52542.35	52504.66	50835.51	43495.05	42279.90	45069.93	46232.99
Czech Republic	19729.87	19916.02	19744.56	17715.62	18463.39	20379.90	23078.57
Cyprus	28912.16	27729.19	27129.63	23333.71	24532.52	26338.69	28689.70
Italy	35053.53	35549.97	35518.42	30230.23	30936.13	32326.84	34483.20
Mexico	10241.73	10725.18	10922.38	9605.95	8739.76	9278.42	9673.44
Colombia	8042.53	8212.67	8114.08	6175.88	5871.22	6375.93	6667.79

In order to identify the weakness of the Italy's higher education system, we calculate the average of the indicator values of the five countries with lower GDP per capita yet higher health score in our model, and compare it with Italy's values. The comparison is shown in the below table and figure.

Table 9. Comparison of Italy and the Average of the Five Countries.

Indicator	Italy	Average of other countries
Gross_enrollment_ratio	61.933	74.94353
Teacher_compesation	31.94337	50.39559
Graduate_rate	37.3413	47.10155
Government_funding	24.49294	21.61304
Household_funding	2.55877	5.987198
Female_student_ratio	0.556313897	0.542087
Inbound_student_ratio	0.053108487	0.099034
Teacher_student_ratio	0.04969432	0.079705

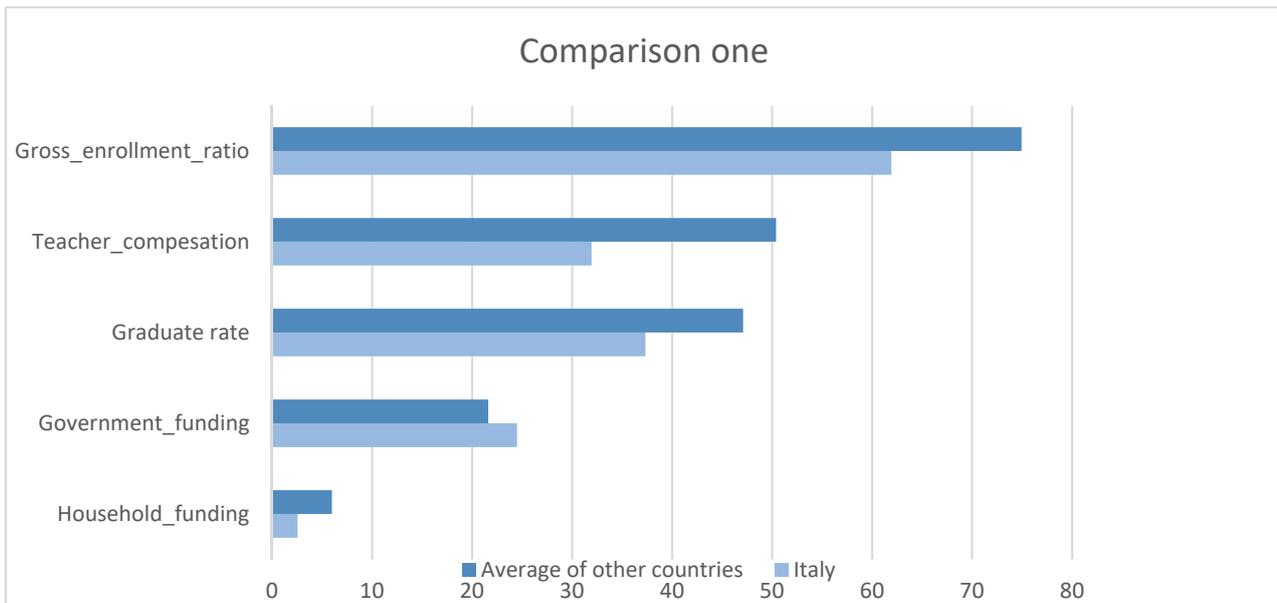


Figure 1. Comparison one

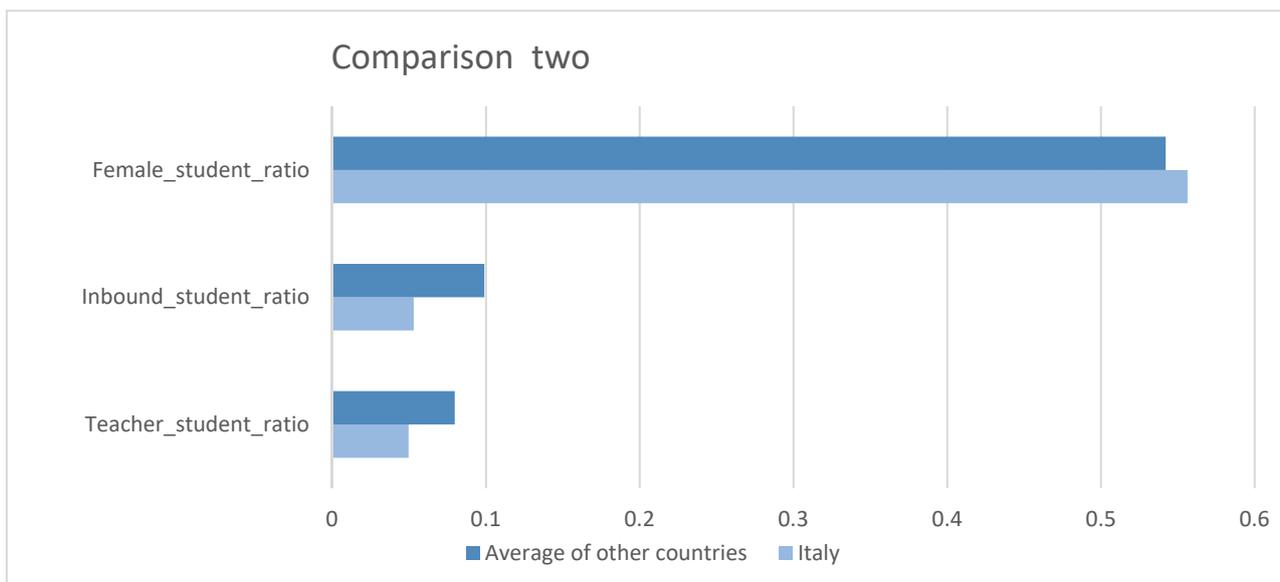


Figure 2. Comparison one

Italian higher education enrolment rates are significantly lower than the average of other countries.

Italian higher education graduation rate is significantly lower than the average of other countries

Teachers' salaries in Italian universities are below the average in other countries

The Teachers-student ratio in Italian universities are below the average in other countries.

The number of international students studying in Italian institutions of higher learning is lower than the average number of international students studying in Institutions of higher learning in other countries.

Italian government spending on higher education is higher than other countries.

Italian household spending on higher education is lower than other countries.

The above is telling us that Italian government is investing more in higher education than other countries, yet is having worse performance.

Hereby we propose the average level of the other five countries as the ideal vision for Italy's higher education and put forward some improvement strategies as well as a timeline of implementation.

5.2. Improvement Plan

Standardize the management of government's investment in higher education, optimize the structure of fund expenditure, and improve the utilization rate of government funds.

To a large extent, the employment environment is the factor that affects the enrollment rate of Italian universities. There is no obvious difference between the employment environment of undergraduates and non undergraduates. Therefore, Italian colleges and universities can develop new disciplines, promote the diversification of professional disciplines, improve the competitiveness of undergraduate graduates in the job market, so as to improve the employment rate, stimulate students' yearning and enthusiasm for colleges and universities, and improve the enrollment rate of Italian colleges and universities

In order to improve the overall level of teachers and promote the average distribution of educational resources, it is necessary to improve the salary level of Italian university teachers and attract more talents to work in universities

The graduation rate of Italian colleges and universities is low, and the teaching quality is relatively backward. However, the Italian government has a large investment in higher education, and generally speaking, the return rate of government investment in higher education is not high. We can improve the quality of education to improve the graduation rate of colleges and universities.

Carry out international academic activities, increase hardware facilities and academic resources, attract more international students and promote international exchanges in higher education. Adopt quota system or scholarship system, improve students' interest in learning.

Through these policies, Italy's higher education system will be improved. However, it is a long process for Italy to move from the current state to the state proposed by our team, so our team has drawn up a time series, which will achieve different goals in different time periods. In 2050, Italy's higher education system will reach a healthy and sustainable state.

5.3. Implementation Timeline

First, we trend the pattern of the evolvement of Italian higher education system. As shown in Figure 2, the growth of Italian higher education system has be stagnate in the past near 20 years. Therefore, the implementation of change would be difficult.

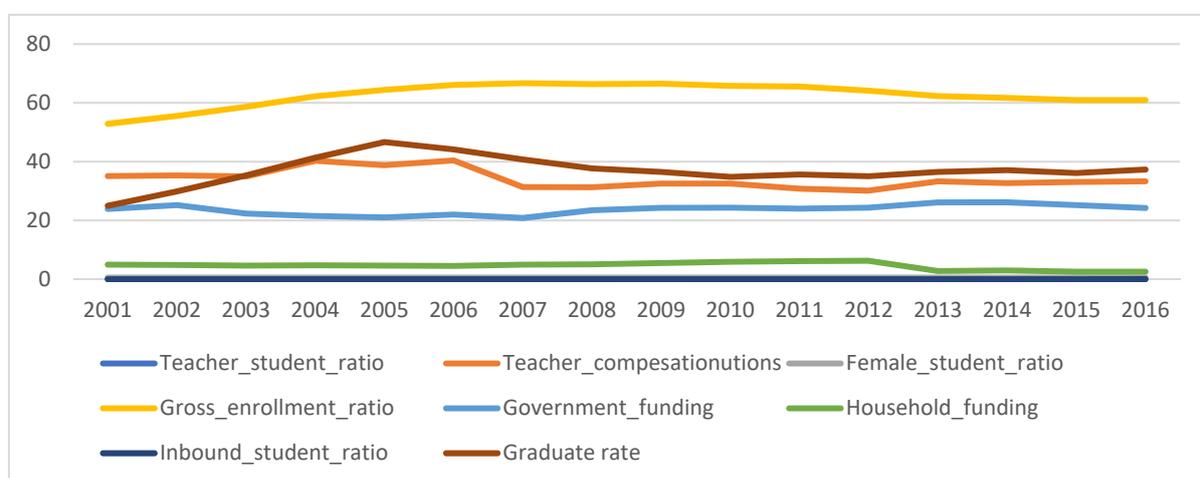


Figure 3. Changes of Italian indicators over the years

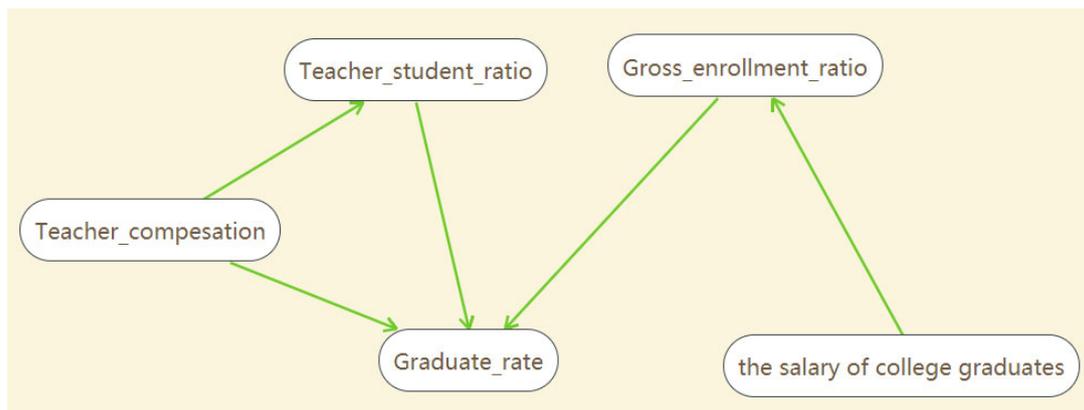


Figure 4. Mind map

If Italy want to have a good graduation rate in higher education, we need to improve the quality of education. To improve the quality of education, we need to improve the salary and quality of teachers. The salary of teachers in Italy is a little far from the average level, and the salary of teachers in Italy has been growing slowly in recent years, so it takes a long time to make the salary of teachers in Italy reach the average level.

The enrollment rate and graduation rate of higher education fluctuate greatly in about five years, so it basically takes five years to achieve a certain goal.

In addition, in order to improve the graduation rate of higher education, we need to improve the quality of teaching, which requires increasing the number of teachers to increase the number of teachers each student can be equipped with. And the increase of teachers' salary will attract more people to be teachers and increase the number of teachers.

According to the survey, the wages of college students and non college students in Italy are almost the same. In order to improve people's enthusiasm for going to university, it is necessary to increase the wages of college students.

After the above measures, people will see the benefits of going to university, thus increasing the enrollment rate of higher education.

Table 10. Implementation schedule

Time	Goal
2021-2029	Improve the salary and quality of teachers
2030-2035	Increase the number of teachers
2036-2040	Improve the graduation rate of higher education
2041-2045	Increase the salary of college graduates
2046-2050	Increase the enrollment rate of higher education

6. Discussion of Real-World Impacts

To students: It enhances the students' interest in the University, gives many people the opportunity to study in Colleges and universities, and improves the overall quality of the people. However, when these college students graduate and go to the society, they are facing more and more complicated employment situation, which increases their employment pressure. It is necessary to adopt quota system or scholarship system, which can expand the access of poor students to higher education, even if these mechanisms may be controversial

To teachers:It increases the employment posts, increases the income, stimulates the enthusiasm of working in Colleges and universities, and then improves the quality of teaching.Teachers have a sense of happiness in their posts, a sense of achievement in their career, and a sense of honor in the society. Teachers have become enviable professions;

To schools:The adjustment and optimization of specialty structure accelerates the modernization of undergraduate majors, expands the educational scale of colleges and universities, and enhances the international reputation of the University,Improve the teaching quality and academic level of the school.

To society:Through these proposed reforms, the number and level of talents in the society will increase to a certain extent, thus affecting and improving the living standard of the society.It has a certain impact on promoting social mobility and reducing the gap between the rich and the poor

To country: On the one hand,it can cultivate a large number of talents. Nowadays, talent is the core element of a country's development. It plays the role of integrating resources, innovating value and creating wealth in national development. In today's world, science and technology progress with each passing day, and knowledge economy is in the ascendant.On the other hand, it also improves the quality of the people and strengthens the country's soft power.At the same time, by increasing international exchanges, we can establish friendly relations with other countries for common progress and development.

Country	Teacher_studen t_ratio	Teacher_compesation	Female_student ratio	Gross_enrollment_ra tio	Government_fundi ng	Household_fundi ng	Inbound_student_ra tio	Graduate rate
Belgium	0.058981	45.26965	0.556289392	79.66173	31.86416	0.96514	0.085386	29.46007
Canada	0.106845	31.71462	0.56054954	68.92251	32.50884	4.87531	0.129172	40.48688
Colombia	0.062492	46.05651	0.529185542	56.43403	20.39238	12.85073	0.00186	23.80567
Cyprus	0.071869	33.45233	0.539778627	75.94081	21.7383	7.93264	0.230895	28.01843
Czech Republic	0.046549	42.58983	0.573815509	64.07869	21.63782	3.09957	0.12543	42.19274
Ireland	0.056032	33.72029	0.515808933	77.78062	20.7645	0.84827	0.088801	45.54535
Italy	0.049694	31.94337	0.556313897	61.933	24.49294	2.55877	0.053108	37.3413
Mexico	0.087442	54.33061	0.501643023	40.22896	25.3676	8.93734	0.005671	27.49514
Portugal	0.095572	69.88526	0.532336301	63.93581	23.22837	7.86023	0.063966	51.4554
Russian Federation	0.101427	56.31749	0.531331492	81.90931	19.64194	4.62035	0.042581	70.28651
Spain	0.083108	49.73303	0.533173348	88.85301	21.81879	6.4232	0.032299	43.55469
Switzerland	0.114584	44.90598	0.497159185	59.56299	37.81399	4.90049	0.177528	52.80235
MAX	0.114584	69.88526	0.573815509	88.85301	37.81399	12.85073	0.230895	70.28651
MIN	0.046549	31.71462	0.497159185	40.22896	19.64194	0.84827	0.00186	23.80567
AVERAGE	0.077883	44.99325	0.535615399	68.27012	25.1058	5.489337	0.086392	41.03704
STD	0.022465	11.07319	0.022464498	12.8059	5.560544	3.370556	0.066248	12.67632

*The data comes from <https://data.worldbank.org.cn/> in 2017

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