

# <sup>1</sup>Academic Ranking of World Universities – Methodologies and Problems

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## Abstract

The Institute of Higher Education, Shanghai Jiao Tong University has published on the web the Academic Ranking of World Universities that has attracted wide attentions worldwide. Institutions are ranked according to their academic or research performance. Ranking indicators include the alumni and staff winning major international awards, highly cited researchers in major research fields, articles published in selected top journals, articles indexed by major citation indexes, and performance per capita. Methodological problems discussed include quantitative versus qualitative evaluation, evaluation of research versus education, variety of institutions, language of publications, selection of awards, and studying or working experience of award winners. Technical problems such as definition of institutions, name expression of institutions, merging and splitting of institutions, searching and attribution of publications are discussed.

## Introduction

In order to find out the gap between Chinese universities and world-class universities, the Institute of Higher Education, Shanghai Jiao Tong University (hereafter called the Ranking Group) has tried to rank research universities in the world by their academic or research performance based on internationally comparable data that everyone could check. Upon the request of many colleagues from different countries, the Ranking Group decided to publish its ranking on the web as the Academic Ranking of World Universities (ARWU). Since the initial publication of ARWU in June 2003, there have been more than one million

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visitors from all over the world, an average of about two thousand visitors everyday. The Ranking Group have received numerous emails, about one third of the emails simply applaud ARWU, 60% of them are positive about ARWU and offer suggestions on improving ARWU. Only about 5% of the emails have negative views on ARWU. In addition, many well-known institutions, organizations, government agencies and the media have reported or cited the results of ARWU.

## **Ranking Methodologies**

### **Selection of Universities**

The Ranking Group has scanned every institution that has any Nobel Laureates, Fields Medals, Highly Cited Researchers, or articles published in *Nature* or *Science*. In addition, major universities of every country with significant amount of articles indexed by Science Citation Index-Expanded (SCIE) and Social Science Citation Index (SSCI) are also included. In total, more than two thousand institutions have been scanned, and about one thousand institutions have been actually ranked. However, only the list of top five hundred institutions has been published on the web.

### **Ranking Criteria and Weights**

Institutions are ranked according to their academic or research performance, ranking indicators include alumni and staff winning Nobel Prizes and Fields Medals, Highly Cited Researchers in twenty-one broad subject categories, articles published in *Nature* and *Science*, articles indexed in Science Citation Index-Expanded (SCIE) and Social Science Citation Index (SSCI), and academic performance with respect to the size of an institution. Table 1 gives the details of the criteria and their weights.

**Table 1 Criteria and Weights for ARWU - 2004**

Criteria	Indicator	Code	Weight
Quality of Education	Alumni of an institution winning Nobel Prizes and Fields Medals	<i>Alumni</i>	10%
Quality of Faculty	Staff of an institution winning Nobel Prizes and Fields Medals	<i>Award</i>	20%
	Highly cited researchers in 21 broad subject categories	<i>HiCi</i>	20%
Research Output	Articles published in <i>Nature</i> and <i>Science</i>	<i>N&amp;S*</i>	20%
	Articles Indexed in Science Citation Index-Expanded and Social Science Citation Index	<i>SCI</i>	20%
Size of Institution	Academic performance with respect to the size of an institution	<i>Size</i>	10%
Total			100%

Data source: <http://ed.sjtu.edu.cn/ranking.htm>.

\* For institutions specialized in humanities and social sciences such as London School of Economics, *N&S* is not considered, and the weight of *N&S* is relocated to other indicators.

### Definition of Indicators

*Alumni* indicates the total number of the alumni of an institution winning Nobel Prizes and Fields Medals. Alumni are defined as those who obtain bachelor, Master's or doctoral degrees from the institution. Different weights are set according to the periods of obtaining degrees. The weight is 100% for alumni obtaining degrees in 1991-2000, 90% for alumni obtaining degrees in 1981-1990, 80% for alumni obtaining degrees in 1971-1980, and so on, and finally 10% for alumni obtaining degrees in 1901-1910. If a person obtains more than one degrees from an institution, the institution is considered once only.

*Award* indicates the total number of the staff of an institution winning Nobel prizes in physics, chemistry, medicine and economics and Fields Medals in mathematics. Staff is defined as those who work at an institution at the time of winning the prize. Different weights are set according to the periods of winning the prizes. The weight is 100% for winners in 2001-2003, 90% for winners in 1991-2000, 80% for winners in 1981-1990, 70% for winners in 1971-1980, and so on, and finally 10% for winners in 1911-1920. If a winner is affiliated with more than one institution, each institution is assigned the reciprocal of the number of institutions. For Nobel prizes, if a prize is shared by more than

one person, weights are set for winners according to their proportion of the prize.

*HiCi* indicates the number of highly cited researchers in twenty-one broad subject categories in life sciences, medicine, physical sciences, engineering and social sciences. These individuals are the most highly cited within each category. The definition of categories and detailed procedures can be found at the website of ISI Web of Knowledge of Thomson Corporation.

*N&S* indicates the number of articles published in *Nature* and *Science* in the past five years. To distinguish the order of author affiliation, a weight of 100% is assigned for corresponding author affiliation, 50% for first author affiliation (second author affiliation if the first author affiliation is the same as corresponding author affiliation), 25% for the next author affiliation, and 10% for all other author affiliations. Only publications of article type are considered.

*SCI* indicates the total number of articles indexed by Science Citation Index-Expanded and Social Science Citation Index in the previous year. Only publications of article type are considered.

*Size* indicates the total scores of the above five indicators divided by the number of full-time equivalent academic staff. If the number of academic staff for institutions of a country cannot be obtained, the weighted total scores of the above five indicators is used. For ARWU 2004, the number of full-time equivalent academic staff is obtained for institutions in USA, China (mainland), Italy, Netherlands, Sweden, and Belgium etc.

### Scoring Procedures

For each indicator, the highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score. The distribution of data for each indicator is examined for any significant distorting effect and standard statistical techniques are used to adjust the indicator if necessary.

Scores for each indicator are weighted to arrive at a final overall score for an institution. The highest scoring institution is assigned a total score of 100, and other institutions are calculated as a percentage of the top total score. The scores are then placed in descending order. An institution's rank reflects the number of institutions that sit above it.

## Ranking Statistics and Analysis

### Statistics of Ranking

Table 2 shows the number and percentage of top institutions by region. North and Latin America has 85% of the top 20 institutions and 55% of the top 100 institutions. For the top 400 and top 500 institutions, the number of European institutions is slightly greater than that of North and Latin American institutions. While the percentage of Asia/Pacific institutions is less than 20% in any range.

**Table 2 Number and Percentage of Top Institutions by Region**

Region	Top 20	Top100	Top 200	Top 300	Top 400	Top 500
North and Latin America	17 (85.0%)	55 (55.0%)	101 (50.2%)	138 (45.9%)	164 (40.7%)	200 (39.9%)
Europe	2 (10.0%)	37 (37.0%)	79 (39.3%)	125 (41.5%)	171 (42.4%)	209 (41.6%)
Asia/Pacific	1 (5.0%)	8 (8.0%)	21 (10.5%)	37 (12.3%)	66 (16.4%)	89 (17.7%)
Africa				1 (0.3%)	2 (0.5%)	4 (0.8%)
<b>Total</b>	20	100	201	301	403	502

Data source: <http://ed.sjtu.edu.cn/ranking.htm>.

The distribution of top institutions among countries is also interesting. As shown in Table 3, only 35 countries have institutions ranked in the top 500. United States has a dominant position, with 85% of the top 20 institutions, 51% of the top 100 institutions, and 45% of the top 200 institutions. United Kingdom performs reasonably well, with about 10% of the top institutions in all the ranges. It is worth noting that most of the top institutions are in developed countries, indicating the very importance of economic power in building world-class universities.

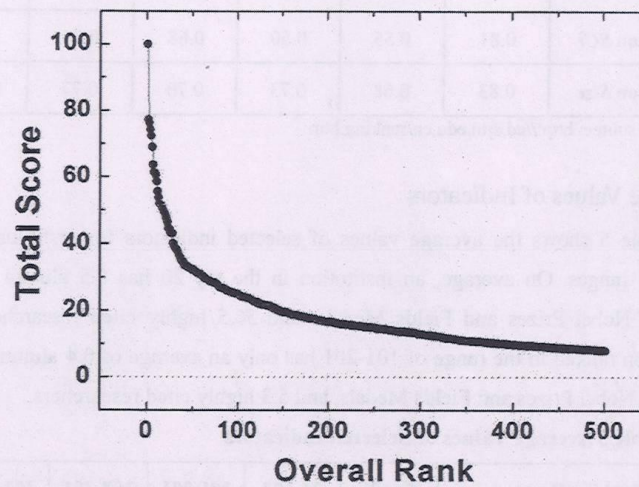
**Table 3 Number of Top Institutions by Country**

	Country	Top 20	Top100	Top 200	Top 300	Top 400	Top 500
1	United States	17	51	90	119	139	170
2	United Kingdom	2	11	18	29	35	42
3	Japan	1	5	9	13	26	36
4	Germany		7	17	27	37	43
5	Canada		4	9	16	19	23
6	France		4	8	13	20	22
7	Sweden		4	6	9	9	10
8	Switzerland		3	6	6	7	8
9	Netherlands		2	7	10	11	12
10	Australia		2	6	8	11	14
11	Italy		1	5	10	16	23
12	Israel		1	3	4	6	7
13	Denmark		1	3	4	5	5
14	Austria		1	1	3	4	5
15	Finland		1	1	2	4	5
16	Norway		1	1	1	3	4
17	Russia		1	1	1	2	2
18	Belgium			4	6	7	7
19	China			1	6	13	16
20	South Korea			1	2	5	8
21	Spain			1	2	4	9
22	Brazil			1	1	3	4
23	Singapore			1	1	2	2
24	Mexico			1	1	1	1
25	New Zealand				2	2	3
26	South Africa				1	2	4
27	Hungary				1	1	3
28	Ireland				1	1	3
29	India				1	1	3
30	Argentina				1	1	1
31	Greece					2	2
32	Poland					2	2
33	Czech					1	1
34	Chile					1	1
35	Portugal						1
	<b>Total</b>	<b>20</b>	<b>100</b>	<b>201</b>	<b>301</b>	<b>403</b>	<b>502</b>

Data source: <http://ed.sjtu.edu.cn/ranking.htm>.

### Distribution of Scores

The distribution of total scores is shown in Figure 1. There is a rapid decrease in the total score with increasing overall rank for the top 100 institutions, particularly for the top 50 institutions. The change of total score is relatively small in the range of 100-500. Therefore, the ranking results are published in groups of 50 institutions in the range of 100-200 and in groups of 100 institutions in the range of 200-500.



*Figure 1. The Distribution of Total Scores as a Function of Overall Rank*

Data source: <http://ed.sjtu.edu.cn/ranking.htm>.

### Correlation Coefficients

Table 4 shows the correlation between scores of indicators for top 500 institutions. All of the correlation coefficients between the total score and the score of each indicator are above 0.80. The scores of different indicators also correlate well among themselves with correlation coefficients higher than 0.50, indicating that the set of indicators is a compact and coherent one.

**Table 4 Correlation Coefficients between Scores of Indicators for 500 Institutions**

Correlation	Total Score	Score on Alumni	Score on Award	Score on HiCi	Score on N&S	Score on SCI	Score on Size
Total Score	1.00						
Score on Alumni	0.80	1.00					
Score on Award	0.84	0.76	1.00				
Score on HiCi	0.90	0.60	0.65	1.00			
Score on N&S	0.93	0.67	0.70	0.86	1.00		
Score on SCI	0.81	0.55	0.50	0.68	0.74	1.00	
Score on Size	0.83	0.68	0.73	0.70	0.77	0.56	1.00

Data source: <http://ed.sjtu.edu.cn/ranking.htm>.

#### Average Values of Indicators

Table 5 shows the average values of selected indicators for institutions ranked in different ranges. On average, an institution in the top 20 has 8.5 alumni and 4.4 staff winning Nobel Prizes and Fields Medals, and 56.5 highly cited researchers. While an institution ranked in the range of 101-201 has only an average of 0.4 alumni and 0.1 staff winning Nobel Prizes and Fields Medals, and 5.3 highly cited researchers.

**Table 5 Average Values of Selected Indicators**

Ranking Range	Top 20	21-100	101-201	202-301	302-403	404-502
Number of Alumni	8.5	1.6	0.4	0.2	0.2	0.0
Number of Award	4.4	0.6	0.1	0.0	0.0	0.0
Number of HiCi	56.5	13.6	5.3	2.3	1.0	0.8
Number of N&S	27.6	6.7	2.7	1.5	0.7	0.4
Number of SCI	4316	2390	1578	1062	787	572

Data source: raw data of Academic Ranking of World Universities – 2004, which was published by the authors of this paper.



## **Methodological Problems and Solutions**

### **Qualitative versus Quantitative**

There is always the complaint that whether the quality of students can be precisely measured by scores. However, universities and professors are continuing to score students without any significant changes, and the students are usually informed that they will not be judged by scores absolutely, the university and the potential employers will have the capacity to make sophisticated, independent judgments.

Similarly, there is always the question that whether the quality of universities can be precisely measured by mere numbers. Therefore, people should be cautious about any ranking and should not rely on any ranking either, including ARWU. Instead, people should use rankings simply as one kind of reference and make their own judgment about ranking results based on ranking methodologies.

### **Education versus Research**

Since different stakeholders have different expectations about quality, the quality of higher education institutions is not easy to compare internationally. It would be impossible to rank the quality of university education worldwide because of the huge differences of universities in the large variety of countries and the technical difficulties in obtaining internationally comparable data.

If one wants to construct a reliable ranking of world universities, the only possible ranking will be a comparative display of research performance. Therefore, the Ranking Group chose to rank research universities in the world by their academic or research performance based on internationally comparable data that everyone could check. No subjective measures were taken. No data is obtained from any kind of university reports.

### Type and Size of Institutions

Many well-known institutions specialized in humanities and social sciences are ranked relatively low partly because of the imbalances in the production of articles among various subject fields. The nominal performance of institutions with medicine faculties appears to be better in the ranking, whereas institutions specialized in humanities and social sciences have relatively low ranks.

The Ranking Group tried hard but was unsuccessful to find additional indicators that are special for humanities and social sciences. However, the indicator of *N&S* is not considered for institutions specialized in humanities and social sciences in ARWU 2004, its weight is relocated to other indicators. In addition, the Ranking Group is studying the rationality of setting special weights for articles indexed by SSCI and for institutions with medicine faculties.

The weight of the *Size* indicator is rather low. Large institutions have relatively high positions in the ranking. The Ranking Group is studying the possibility of providing separate rankings with and without the *size* indicator. For ranking with the *size* indicator, the weight of the *size* indicator could be as high as 50%. Furthermore, there are difficulties in defining academic staff and obtaining internationally comparable data.

### Language and Type of Publications

Since English is the international language in the academic world, scholars in English-speaking institutions are more closely integrated into the global academic environment than scholars outside the English-speaking world. As a result, university ranking based on research performance may inevitably lead to bias against institutions outside the English-speaking world. One possible solution would be to set special weight on publications with non-native languages.

Only publication of original article type is considered in ARWU 2004. Papers of communication type are important sources of original research; they are not considered based on the assumption that most of the work in communications is eventually published in articles. Academic books are important sources of original research and are more common in some research fields than in others. Books are not considered due to the technical difficulties in obtaining internationally comparable data.

### Selection of Awards and Experience of Award Winners

There are many well-known awards such as Nobel Prize, Fields Medal, Abel Prize, and Pulitzer Prize. However, Nobel Prize and Fields Medal are mostly recognized by the international academic community.

There are concerns about the studying or working experience of award winners. Award winners may get their awards at institutions that are not the ones for them to do the respective research work. Similarly, institutions for award winners to obtain their degrees and those for them to spend most of their study time may not be the same. In addition, post-doctoral training and other non-degree training are not considered.

### Technical Problems and Solutions

#### Definition of Institutions

Institutions in the multi-campus university systems of United States are treated as separate institutions according to the Integrated Postsecondary Education Data System of the National Center for Education Statistics and the Carnegie Classification of Institutions of Higher Education. For example, University of California – Los Angeles is ranked as an independent institution. Similarly, Imperial College of University of London is ranked separately.

Institutions or research organizations affiliated to a university are treated according to their own expression in author affiliations. If the authors identify themselves as members of a university in their affiliations, it will be considered accordingly in the ranking. Typical examples include the *Ecole Polytechnique* of Montreal affiliated to University of Montreal in Canada. Similar treatment has been performed to CNRS laboratories affiliated to French universities.

Hospitals affiliated to universities are very complex problems in many countries. Some hospitals do not wish to include the university name in their affiliation while some universities do not wish to include papers published by hospital staff in their statistics. Therefore, hospitals affiliated to universities are treated according to their own expression

in their author affiliations.

Furthermore, it's the responsibility of the universities and their affiliated units to write the proper affiliations in their publications; it should not be the responsibility of database manufacturers and users.

### Name Expression of Institutions

Many universities themselves have more than one commonly used name. In France, for example, University of Paris 6 is also called Pierre & Marie Curie University. In the United States, Virginia Tech is the same as Virginia Polytechnic and State University. In China, traditional spelling of names is used for a number of institutions, such as Tsinghua University for Qinghua University.

For institutions in non-English speaking countries, there often exist different names for the same institution or the same name for different institutions due to variations in translation. For example, Université Libre de Bruxelles and Vrije Universiteit Brussel in Belgium share the same English name of Free University of Brussels. *Universittat zu Koln* in Germany may be translated to University of Koeln or University of Cologne.

Abbreviated names are commonly used for a large number of institutions. For example, ETHZ is used for the Swiss Federal Institute of Technology of Zurich in Switzerland; UMPC is used for University of Paris 6 in France.

### Merging and Splitting of Institutions

The names of institutions have been changing significantly as a result of merging, splitting, discontinuing, and name changing. For example, Berlin University had several Nobel Prize winners before the Second World War, both Humboldt University of Berlin and Free University of Berlin claimed the right of inheriting the Nobel Prizes of the Berlin University.

The names of institutions are continuing to change now days. For example, University of Manchester and UMIST in the United Kingdom were merged into one institution in October 2004. University of Kwazulu-Natal in South Africa was a result of merger between University of Natal and University of Durban-Westville in January 2004. University of Innsbruck in Austria was splitted into two independent universities, the

University of Innsbruck and the Innsbruck Medical University.

### Database Searching and Attribution of Publications

One must be very careful about the keywords in searching data for institutions in the same cities. For example, if one simply searches Beijing University, he would obtain the results for a dozen of universities in the city of Beijing.

For the Highly Cited Researchers, the Ranking Group downloaded the full list from the ISI database and identified the affiliation of every researcher one by one. Researchers in a regular department, institute or school of a university without mentioning the university in their affiliation were carefully attributed to the right university.

For articles published in *Nature* and *Science*, the Ranking Group searched the ISI database country by country and counted every article one by one. Again, articles of a regular department, institute or school of a university without mentioning the university in their affiliation were carefully attributed to the right university.

For articles indexed in the Science Citation Index Expanded and Social Science Citation Index, the Ranking Group tried every possible means to find solutions for the possible problems and solved most of the problems.

## Concluding Remarks

### Controversy of University Ranking

Any ranking is controversial and no ranking is absolutely objective. Nevertheless, university rankings become popular in many countries. Whether universities and other organizations agree with the various ranking systems; ranking systems clearly are here to stay. The key issue then becomes how to improve ranking systems for the benefits of higher education.

### Features of ARWU

ARWU is academic research for personal interests and is done independently without any external support. It uses a few carefully selected, non-subjective criteria and

internationally comparable data that everyone could verify in some way. It provides the ranking results in groups of fifty or one hundred for institutions in the range of 100-500, considering the significance of difference in scores.

#### Future Efforts

The Ranking Group will continue their efforts and update ARWU annually with necessary modifications. The Ranking Group are investigating the possibilities of providing lists of top universities with engineering (technology) or medical orientation, as well as the possibilities of ranking universities by broad subject areas such as social sciences, physical sciences, engineering and technology, life sciences and medicine.

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