A quantitative approach to world university rankings

Nadim Mahassen

Center for World University Rankings

ABSTRACT

World university rankings are lists of higher education institutions ordered using a combination of indicators. Some rankings rely mainly on research indicators, while others place a great deal of emphasis on opinion based surveys. Up to now, there has been no ranking measuring the quality of the learning environment as well as research without relying on surveys and university data submissions. Here it is shown that a ranking measuring the quality of education and training of students as well as the prestige of the faculty and the quality of their research could be constructed based solely on verifiable data and robust indicators. It is found that, in addition to research performance, the quality of an institution's alumni significantly affects its ranking. The results of this study will be of interest to students, academics, university administrators, and governments from around the world.

INTRODUCTION

In recent years, there has been an increasing interest in world university rankings. The Academic Ranking of World Universities[1], first published in 2003, was the first attempt at a global ranking. Despite not using subjective indicators, the ranking has the following drawbacks: 1) It is weighted toward institutions whose faculty or alumni have won Nobel Prizes and Fields Medals, but ignores other major awards, medals, and prizes in other academic disciplines. 2) It relies mainly on research indicators, without properly assessing the quality of education and training of students. 3) Published papers are given the same weight regardless of the journals in which they were published. Except for publications in *Nature* and *Science*, papers published in prestigious journals such as *New England Journal of Medicine* are given the same weight as papers published in any other scientific journal listed in the ISI Web of Science database[2]. 4) Publications

[1] http://www.shanghairanking.com
[2] http://www.webofknowledge.com

in arts and humanities are not counted. 5) Perhaps the biggest drawback is the Highly-Cited indicator. A university could boost its ranking by offering part-time contracts to highly-cited researchers in exchange of adding the institution's name as a second affiliation on ISI's list of highly-cited researchers[3]. Another ranking, now called the QS World University Rankings[4], has been published since 2004. One of its shortcomings is its reliance on reputational indicators for half of its analysis. Another shortcoming is the faculty to student ratio indicator, where the number of faculty could be inflated by including academic-related and non-teaching staff, resulting in the indicator failing to reflect the quality of teaching. A third ranking, the Times Higher Education World University Rankings[5], has been released since 2010. As with the QS ranking, its main drawback is that it relies heavily on surveys, which make up about one third of its analysis. Roughly another third is made up of data submitted by universities, which could be manipulated in order to move up in the ranking. In this study, universities are ranked according to seven objective and robust indicators, which are explained in detail below. The full list of the world's top 2000 institutions can be found at the website of the Center for World University Rankings[6].

METHODOLOGY

Research Output: For this indicator, the Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index from the Web of Science's website are used to sort universities according to their total number of "Article" publications during the last 10 full years.

High-Quality Publications: For this indicator, the journals obtained from Clarivate Analytics' Journal Citation Reports (*JCR*) website[7] are mapped into 23 broad fields: agricultural sciences, arts & humanities, biology & biochemistry, chemistry, clinical medicine, computer science, economics & business, engineering, environment/ecology, geosciences, immunology, materials science, mathematics, microbiology, molecular biology & genetics, multidisciplinary sciences, neuroscience & behavior, pharmacology & toxicology, physics, plant & animal science, psychiatry/psychology, general social

[3] http://www.highlycited.com
[4] http://www.topuniversities.com
[5] http://www.timeshighereducation.com/world-university-rankings
[6] http://www.cwur.org
[7] https://jcr.clarivate.com

sciences, and space sciences. The "Article Influence Score" (which measures the average influence, per article, of the papers in a journal) will be used to rank the journals. Here, a citation from a high-quality journal counts more than a citation from a lesser quality journal. In addition, unlike the Impact Factor, self-citations are excluded. For a given broad field BF_i (except arts & humanities), journals are sorted according to their Article Influence Score (*AIS*), from largest to smallest. A list L_i of journals with non-zero *AIS* can then be obtained. If N_i is the total number of articles in L_i listed in the most recent edition of *JCR*, the journals chosen for this indicator are the ones with the highest *AIS* in L_i and containing between them $0.25N_i$ articles in total. Repeating this algorithm for all the 23 broad fields, we obtain a combined list $J_{Sci\text{-}Soc}$ of high-quality journals in Science and Social Sciences. For arts and humanities, let $J_{a\&h}$ be the list of all journals in the Arts & Humanities Citation Index, where each article is assigned a weight of 0.25. Using the Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index from the Web of Science's website, universities are sorted according to the sum of the number of "Article" publications in journals listed in $J_{Sci\text{-}Soc}$ and $J_{a\&h}$ during the last 10 full years.

Influence: Here, an Influential Journal is defined as one that belongs to the list of journals where $0.25N_i$ and the weight 0.25 in the above indicator are replaced by $0.01N_i$ and 0.01 respectively. Using this criteria, universities are sorted according the number of "Article" publications in the last 10 full years in these influential journals.

Citations: If Y is the current year then, for each of the 23 broad fields, the most cited "Article" publications are counted between the years $Y - 2$ and $Y - 11$ in the Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index. The cutoff for the number of highly-cited papers in a given broad field is proportional to the total number of "Article" publications in that field. The cutoffs are chosen in such a way that their sum equals 50000. By considering all 23 broad fields, universities are sorted according to the total number of the highly-cited publications.

Quality of Faculty: This indicator measures the weighted number of faculty members of an institution who have won the following awards, medals, and prizes covering virtually all academic disciplines: Wolf Prize

in Agriculture, Praemium Imperiale, Kluge Prize, Louisa Gross Horwitz Prize, Nobel Prize in Chemistry, Nobel Prize in Physiology or Medicine, Turing Award, Tyler Prize for Environmental Achievement, Nobel Memorial Prize in Economic Sciences, Herbert Simon Award, Charles Stark Draper Prize, Queen Elizabeth Prize for Engineering, Crafoord Prize in Geosciences, Vetlesen Prize, Paul Ehrlich and Ludwig Darmstaedter Prize, Kyoto Prize in Materials Science and Engineering, Von Hippel Award, Fields Medal, Abel Prize, Robert Koch Prize, Gruber Prize in Genetics, Albert Einstein World Award of Science, Gruber Prize in Neuroscience, Kavli Prize in Neuroscience, Robert R. Ruffolo Career Achievement Award, John J. Abel Award, Nobel Prize in Physics, Linnean Medal, Jean Delay Prize, Grawemeyer Award in Psychology, Holberg International Memorial Prize, Albert O. Hirschman Prize, Talcott Parsons Prize, A.SK Social Science Award, Crafoord Prize in Astronomy, and Kavli Prize in Astrophysics (this list could be modified in the future if necessary). Faculty members are defined here as those who were employed at the institution in question at the time of winning the award, medal, or prize. Faculty members are assigned r_F points according to the following formula:

$$r_F = C \cdot \exp\left[-k \cdot ((Y-1)-x)^2\right]$$

where Y is the current year and x is the year when an award/prize/medal was made to the faculty member. The constant C is set to 1 except in very rare cases where a faculty member holds more than one full-time position (in which case, C is equal to the reciprocal of the number of institutions). The positive constant k is chosen so that $r_F = 0.01$ when $(Y - 1) - x = 99$ and $C = 1$. This gives $k = 99^{-2}\ln(100)$. For each award/medal/prize(s) associated with a given broad field, let R_F be the sum of all r_F and P be the ratio of article publications in the last 10 years in this given broad field to the total 23 broad fields combined. For each faculty member, $(100/R_F) \cdot P \cdot r_F$ points are assigned to his/her university. Adding up these points for each institution for all 23 broad fields, and calling the sum p_F, universities can be sorted based on the total points p_F.

Alumni Employment: This indicator measures the weighted average number (per year) of a university's alumni who have held CEO positions since 2011 at the world's top 2000 public companies relative to the

university's size. The top companies are those listed on the Forbes Global 2000 list[8]. An alumnus/alumna is defined as a student who graduated with a Bachelor, Master, or Doctorate degree (or their equivalents). If more than one degree was obtained from a given institution, the institution is considered only once. In very rare cases where an alumnus/alumna is a CEO of more than one company, his/her educational institution will be considered only once. The weighting factor is similar to the quantity $(1/C)\cdot r_F$ above with x being the year the Forbes list is published. If an institution has a yearly weighted average of q CEO alumni, it will be assigned points according to the formula

$$p_E = \frac{q^2}{\max\ (n,\ 2000)}$$

where n is the current number of students enrolled at the institution, which can be obtained from national agencies. The above formula increasingly rewards institutions that have, relative to their size, a high number of CEOs. It also ensures that small fluctuations in the number of CEOs from year to year for institutions with a very small student body don't have a significant effect. The ratio p_E measures the performance of the training programs of universities, based on the professional future of their alumni.

Quality of Education: This indicator measures the weighted number of a university's alumni who have won major awards, medals, and prizes relative to the university's size. Here, alumni are defined as students who obtained Bachelor, Master, or Doctoral degrees (or their equivalents) and won awards, medals, and prizes listed under "Quality of Faculty". For each alumnus/alumna, r_A points are assigned to him/her according to the following formula:

$$r_A = \exp\left[-k\cdot((Y-1)-x)^2\right]$$

where Y is the current year, x is the year when the degree was awarded, and $k = 99^{-2}\ln(100)$ as in the "Quality of Faculty" indicator. If an alumnus/alumna obtains more than one degree from an institution, the institution will be considered only once and the date of the last degree will be used for x. For each award/medal/prize(s) associated with a given broad field, let R_A be the sum of all r_A and P as defined above. Let s_A be the sum of $(100/R_A)\cdot P\cdot r_A$ points of an institution for all the 23 broad fields. As in the previous indicator, each university is assigned points according to:

[8] http://www.forbes.com/global2000

$$p_A = \frac{{s_A}^2}{\max\ (n,\ 2000)}.$$

This ratio measures the quality of education of a university based on the academic future of its alumni.

Aggregation and Scoring: Each indicator is assigned a weighting factor equals to 0.1 (10%) except for the quality of education and alumni employment indicators which have a weighting factor of 0.25 (25%) each. An institution's pre-final score S_{pf} is given by the geometric average

$$S_{pf} = \prod_{k=1}^{7} (1 + (100 t_k / t_{Top}))^{w_k} - 1$$

where t_k is the university's score on indicator k, t_{Top} is the score of the top performing institution on that indicator, and w_k is the weighting factor for the corresponding indicator. Universities are then ranked based on their pre-final scores and assigned final scores based on a scaled 0-100 Gaussian bell curve.