

# A quantitative approach to world university rankings

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## 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, alumni employment, quality of faculty, and research performance could be constructed based solely on verifiable data and robust indicators. It is found that, in addition to research, 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<sup>1</sup>, 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 alumni employment. 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<sup>2</sup>. 4) Publications

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<sup>1</sup> <http://www.shanghairanking.com>

<sup>2</sup> <http://www.webofknowledge.com>

in arts and humanities are not counted. Another ranking, now called the QS World University Rankings<sup>3</sup>, 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<sup>4</sup>, 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<sup>5</sup>.

## 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<sup>6</sup> are mapped into 23 broad fields: agricultural sciences, arts & humanities, biology & biochemistry, chemistry, clinical medicine, computer science, ecology/environment, economics & business, engineering, geosciences, immunology, materials science, mathematics, microbiology, molecular biology & genetics, multidisciplinary sciences, neuroscience & behavior, pharmacology & toxicology, physics, plant & animal science, psychiatry/psychology, general social sciences, and space sciences. The "Article Influence Score" (which measures the average influence, per article, of the papers in a journal) is 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

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<sup>3</sup> <https://www.topuniversities.com>

<sup>4</sup> <https://www.timeshighereducation.com/world-university-rankings>

<sup>5</sup> <https://www.cwur.org>

<sup>6</sup> <https://jcr.clarivate.com>

a given broad field  $BF_i$  (except arts & humanities), journals are sorted according to their Article Influence Score ( $AIS$ ), from largest to smallest, and a sorted list  $L_i$  of journals can then be obtained. If  $N_i$  is the total number of research articles in the last 10 full years in  $BF_i$ , the ones chosen for this indicator,  $n_i$ , are those that make up  $0.25N_i$  and found at the top of the list  $L_i$ . For arts & humanities, each article in the Arts & Humanities Citation Index is assigned a weight of 0.25. Universities are then sorted according to the combined number of their articles in the 22  $n_i$  added to their weighted arts & humanities articles.

**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  $0.05N_i$  and 0.05, respectively. Using this criterion, universities are sorted according to 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 1% of the total number of “Article” publications in that field. 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 the 23 broad disciplines listed earlier: Wolf Prize in Agriculture, Praemium Imperiale, Kluge Prize, Louisa Gross Horwitz Prize, Nobel Prize in Chemistry, Nobel Prize in Physiology or Medicine, Turing Award, Crafoord Prize in Biosciences, 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, Novartis Prizes for Immunology, German Immunology Award, Kyoto Prize in Materials Science and Engineering, Von Hippel Award, Abel Prize, Fields Medal, Microbiology Society Prize Medal, Mendel Medal of the Leopoldina, Gruber Prize in Genetics, Albert Einstein World Award of Science, Kavli Prize in Neuroscience, NAS Award in the Neurosciences, Robert R. Ruffolo Career

Achievement Award, Leading Edge in Basic Science Award, Nobel Prize in Physics, Linnean Medal, Jean Delay Prize, Grawemeyer Award in Psychology, Holberg International Memorial Prize, 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  $r_F = C \cdot 0.99^{((Y - 1) - x)}$ , where  $Y$  is the current year and  $x$  is the year when an award/prize/medal was given 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). 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<sup>7</sup>. 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. 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  $p_E = (q^2)/n$ , 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. The ratio  $p_E$  measures the performance of the training programs of universities, based on the professional future of their alumni.

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<sup>7</sup> <http://www.forbes.com/global2000>

**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  $r_A = 0.99^{((Y-1)-x)}$ , where  $Y$  is the current year and  $x$  is the year when an award/prize/medal was given to the alumnus/alumna. If he/she obtains more than one degree from an institution, the institution will be considered only once. 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  $p_A = (s_A^2)/n$ . 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

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

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.