Are University Rankings Statistically Significant? A Comparison among Chinese Universities and with the USA

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Abstract

Purpose: Building on Leydesdorff, Bornmann, and Mingers (2019), we elaborate the differences between Tsinghua and Zhejiang University as an empirical example. We address the question of whether differences are statistically significant in the rankings of Chinese universities. We propose methods for measuring statistical significance among different universities within or among countries.

Design/methodology/approach: Based on *z*-testing and overlapping confidence intervals, and using data about 205 Chinese universities included in the Leiden Rankings 2020, we argue that three main groups of Chinese research universities can be distinguished (low, middle, and high).

Findings: When the sample of 205 Chinese universities is merged with the 197 US universities included in Leiden Rankings 2020, the results similarly indicate three main groups: low, middle, and high. Using this data (Leiden Rankings and Web of Science), the *z*-scores of the Chinese universities are significantly below those of the US universities albeit with some overlap.

Research limitations: We show empirically that differences in ranking may be due to changes in the data, the models, or the modeling effects on the data. The scientometric groupings are not always stable when we use different methods.

Practical implications: Differences among universities can be tested for their statistical significance. The statistics relativize the values of decimals in the rankings. One can operate with a scheme of low/middle/high in policy debates and leave the more fine-grained rankings of individual universities to operational management and local settings.

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Originality/value: In the discussion about the rankings of universities, the question of whether differences are statistically significant, has, in our opinion, insufficiently been addressed in research evaluations.

Keywords Ranking; University; China; Significance of differences; Indicators

1 Introduction

Classifications and rankings are based on assumptions and decisions about parameters. For example, Harvard University is listed at the top in many rankings. However, when one controls for the budget by dividing the numbers of publications and/or citations (output) by budget (input), other universities come to the fore. Leydesdorff and Wagner (2009), for example, found Eastern-European universities (Poland, Slovakia) as most efficient in terms of output/dollar, because of the relatively low costs of skilled labour in these countries at the time. The ranked order is conditioned by the choice of indicators.

In China, for example, the mathematics department of Qufu Normal University unexpectedly led the ranking of US News with a 19th position worldwide.^① This unexpected result generated a heated discussion about rankings. Qufu Normal University is a provincial university. How could it be ahead of Peking University, which is traditionally believed to have the strongest mathematics department in China. Shandong University of Science and Technology was ranked third, trailing Peking University by only 0.1 points (Tsinghua University ranked sixth.) However, the majors in mathematics of these two universities are rated relatively low when using other indicators including international collaborations. In sum, a rank-order is conditioned by the choice of indicators and by how the various indicators are weighed in the attribution (Shin, Toutkoushian, & Teichler, 2011).

Comparing universities may be even more complex than comparing nations. While nations can be expected to cover portfolios of standardized measurements,^② universities can be specialized by discipline or by mission (e.g. agricultural universities). What counts as “output” of universities is debatable. Furthermore, universities provide higher-education, and one can argue that this task should be appreciated in a ranking, even if it is difficult to measure. University ranking services seek to compare such heterogeneous indicators by weighting, summing, or averaging partial indicators, but often without giving much value to mission-orientation and social relevance.

^① <https://www.usnews.com/education/best-global-universities/china/mathematics>; retrieved 27 October 2020.

^② See, for example, OECD’s Frascati Manual: <https://www.oecd.org/publications/frascati-manual-2015-9789264239012-en.htm>

The reliability and reproducibility of yearly rankings is low because the models are based on specific choices in a parameter space of possible choices. Gingras (2016), for example, concluded “that annual rankings of universities, be they based on surveys, bibliometrics, or webometrics, have no foundation in methodology and can only be explained as marketing strategies on the part of the producers of these rankings.” Others have pointed to the reputational effects in rankings. Rankings can instantiate historical power structures (Bowman & Bastedo, 2011). However, numbers can also provide a new perspective because ongoing changes may have gone hitherto unnoticed. We shall provide examples of such unexpected developments below.

In our opinion, statisticians and bibliometricians have made progress during the last decade in developing arguments for making informed decisions about the data and relevant methodologies for comparing institutions. The rankings no longer have to be arbitrary and subjective combinations of surveys and partial indicators. However, they remain constructs which enable us to distinguish among universities in specific terms. For example, the Leiden Rankings (LR) of research universities stand out in terms of their transparency and clear objectives. The objective of the LR exercises is to rank research universities exclusively in terms of their publications and citations as output, without accounting for other differences.

2 Decisions about data

We use in this study LR and not, for example, the Shanghai Jiaotong University Ranking, because the data curation is bibliometrically transparent and easily reproducible in LR. Our analytical and statistical arguments, however, can analogously be applied to the other ranking (e.g. Peters, 2017; Shin, Toutkoushian, & Teichler, 2011). In addition to providing the rankings online (<https://www.leidenranking.com/ranking/2020/list>), the yearly source data for LR are freely available in an Excel file for secondary analysis. This data is derived from the Web of Science of the Institute of Scientific Information (ISI/Clarivate) in Philadelphia. The address information is disambiguated and reorganized by the Centre for Science and Technology Studies (CWTS) in Leiden.

LR does not take into account conference proceedings and book publications; it is exclusively based on research articles and reviews published in the journals included in the Web of Science.[®] Consequently, the coverage may favor work in

[®] Clarivate’s criterion for classifying papers as reviews is as follows: “In the *JCR* system any article containing more than 100 references is coded as a review. Articles in ‘review’ sections of research or clinical journals are also coded as reviews, as are articles whose titles contain the word ‘review’ or ‘overview’” (at http://thomsonreuters.com/products_services/science/free/essays/impact_factor/ (retrieved 8 April 2012); <https://clarivate.com/webofsciencelgroup/essays/impact-factor/> (retrieved on 29 August 2020)).

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the natural and engineering sciences more than the social science and humanities (Sivertsen, 2016). However, this data can be considered as an attempt to capture the most intellectual contribution to knowledge production among the numerous outputs of research universities (Garfield, 1971). A major decision remains thereupon to attribute co-authored papers for a full count to each of the (co-)authors and their home institutions or to attribute this credit proportionally (so-called “fractional counting”); both of these methods are made available in the Excel files.

The full counting method gives a full point to each author and her institutional address. Fractional counting divides the attribution by the number of authors or institutions. Bibliometrically, fractional counting has the advantage that each publication is eventually counted as one full point and thus percentages add up to hundred (Anderson et al., 1988). Among the possible counting rules, LR uses fractional counting at the institutional level. For example, if a publication is co-authored by three researchers and two of these researchers are affiliated with a particular university, the publication has a weight of $2 / 3 = 0.67$ in the attribution of the scientific impact to this university (Sivertsen, Rousseau, & Zhang, 2019).

Another important decision is the time window used to harvest publications and citations, respectively. LR uses four-year periods for cited publications. The last interval for LR 2020 is 2015–2018; the count included citations to publications in these four years cumulatively. The resulting file with input data for this study contained ranks for 1,176 research universities in 65 countries in the preceding years in intervals of four years (Table 1). Rankings are provided both fractionally and as whole counts. In terms of disciplines, data is provided for “All sciences” and five major fields on the basis of relevant journal categories: (i) biomedical and health sciences, (ii) life and earth sciences, (iii) mathematics and computer science, (iv) physical sciences and engineering, and (v) social sciences and humanities. In this study, we limit the analysis first to “All sciences,” the last available period (2015–2018), and fractional counting. However, this analysis can be repeated analogously using subsets with other parameter choices.

Our sample contains 205 Chinese universities (Table 2) covered by LR 2020. This data was further processed by us with dedicated routines, which are online available at <http://www.leydesdorff.net/software/leiden> (Leydesdorff, Bornmann, & Mingers, 2019). These routines analyze the comparisons in each nation. China and the US, however, are represented in LR 2020 with 205 and 198 universities, respectively, making comparisons possible. For example, one can compare Harvard with Stanford as US universities, and—as we shall see below—it is possible to compare them with Tsinghua or Zhejiang University.

Table 1. Number of research universities included in LR 2020 for respective countries.

Country (top 10 of 65)	N of universities	
China	205	
United States	198	
United Kingdom	58	
Germany	54	
Japan	53	
South Korea	44	
Italy	41	
Spain	41	
India	36	
Iran	36	%
sum	766	65.1%
<55 other countries>	$= (1,176 - 766) = 410$	34.9%
65 countries	1,176	100%

3 Methods

3.1 Statistical significance

The values of indicators are almost by definition unequal between two measurements, but one can ask whether differences are statistically significant or fall within the margin of error. In a study about German, British, and US universities, Leydesdorff, Bornmann, and Mingers (2019) proposed three statistics for distinguishing among groups of universities: (i) overlapping confidence intervals, (ii) *z*-tests based on differences between observed and expected values of the percentage publications in the top 10% group (PP-top10%)—and (iii) effect sizes (Cohen, 1988). Although many statisticians nowadays have a preference for the latter measure (Schneider, 2015; Waltman, 2016), effect sizes are less known to practitioners. Power analysis based on effect sizes is sometimes considered to be of “practical significance” (Cumming, 2013; Wasserstein & Lazar, 2016). However, the scientometric interpretations of the effect sizes in our previous study were not convincing.

Building on Leydesdorff, Bornmann, and Mingers (2019), we elaborate the differences between Tsinghua and Zhejiang University numerically and step-by-step: (i) we address the question of whether differences are statistically significant in the rankings of Chinese universities; (ii) we propose methods for measuring statistical significance among different universities within or among countries. We limit the discussion here to *z*-testing and overlapping confidence intervals. Using the *z*-scores, one can test the differences for significance and thus generate groups of nodes with links among them indicating group membership. These results can be

analyzed and visualized as clusters. The z -scores can also be used as quantitative measures of differences among nodes (universities) and links (between universities).

We limit the discussion here to z -testing and overlapping confidence intervals. When the differences between two universities are not significantly different, they can be grouped together. Using the z -scores or the relative overlaps, one can test the differences and thus generate groups of nodes with links among them indicating group membership. These results can be analyzed and visualized as clusters. The z -scores can also be used as quantitative measures of differences among nodes (universities) and links (between universities).

3.2 Observed versus Expected

Most commonly, one tests for the significance of the differences between *mean* values of variables or, in the case of citation analysis, between the so-called *c/p*-ratios—that is, the *mean* numbers of citations per publication. However, scientometric distributions are highly skewed; the mean is therefore not a meaningful indicator of the central tendency in the distribution.[®] An alternative could be found in using the median which is by definition equal to the top 50% of the distribution. Given the skew of the distribution, however, quality indicators can also focus on the numbers of top 10% or even top 1% most-highly cited papers (Bornmann & Mutz, 2011; Leydesdorff et al., 2011; McAllister, Narin, & Corrigan, 1983; Tijssen, Visser, & van Leeuwen, 2002).

Counts allow for significance testing of the differences between expected and observed values using non-parametric statistics. For example, chi-square is formulated as follows:

$$\chi^2 = \sum_{i=1}^n \frac{(Observed_i - Expected_i)^2}{Expected_i} \quad (1)$$

Significance of the resulting chi-square values can be looked-up in any table of chi-square values; for example, at the Internet.

Additionally, and in this context importantly, the individual terms before the squaring $\left[\frac{(Observed_i - Expected_i)}{\sqrt{Expected_i}} \right]$ are the so-called standardized residuals of the chi-square. Any residual with an absolute value > 1.96 is significant at the 5% level, and any residual > 2.576 is significant at the 1% level. In other words, the residuals are z -scores enabling a detailed investigation of differences at the level of each individual cell of a matrix.

[®] The so-called “crown indicator” in scientometrics (van Raan et al., 2010; Waltman et al., 2011) is unfortunately the *Mean Normalized Citation Score* (MNCS). As noted, the *mean* is an unfortunate choice as a central-tendency statistic of a skewed distribution.

Let us elaborate with a numerical example comparing Tsinghua and Zhejiang University. Table 2a shows the values obtained from LR 2020 data for these two leading universities.

Table 2a. Observed values of top 10% cited papers for Tsinghua and Zhejiang University during the period 2015–2019 (fractional counting, all sciences).

Observed values	top 10%	non-top	total p
Tsinghua	2,738	17,164	19,902
Zhejiang	2,604	20,906	23,510
	5,342	38,070	43,412

The expected values can be derived from the observed ones by using the margin-totals and grand-total of the cross-table as follows: $Expectation(ij) = (\sum_j \Sigma_i) / \Sigma_{..}$. In other words, the product of the column total and the row total is divided by the grand total of the matrix. Applying this counting rule, the expected number of papers in the top 10% category of Tsinghua University is $(19902 * 5342) / 43412 = 2449.01$. This value is written in the top-left cell of Table 2b.

Table 2b. Expected values of top 10% cited papers for Tsinghua and Zhejiang University.

Expected values	top 10%	non-top	total p
Tsinghua	2,449.01	17,452.99	19,902.00
Zhejiang	2,892.99	20,617.01	23,510.00
	5,356.09	38,055.91	43,412.00

Using Eq. 1, Table 3 shows the contributions of cell values to the chi-square. The sum of the values in Table 3 is the chi-square; in this case 71.80. The corresponding p -value is < 0.001 and thus the differences are statistically significant.

Table 3. Chi-square for the comparison of Tsinghua and Zhejiang University in LR 2020.

Chi-square	top 10%	non-top	
Tsinghua	34.10	4.79	38.89
Zhejiang	28.87	4.05	32.92
		$\chi^2 =$	71.80

Table 4. Standardized residuals of the chi-square values in Table 4.

	Top 10%	Non-top
Tsinghua	5.84	-2.19
Zhejiang	-5.37	2.01

Table 4 adds the residuals of the chi-square for this data. Tsinghua ranks significantly above expectation in the top 10% category ($z > 2.576$), and non-significantly below expectation in the other publications. For Zhejiang the opposite

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is the case. In conclusion: these two universities cannot be considered statistically as belonging to the same group.

3.3 z-test

Without prior knowledge of historical or social contexts, one would expect that 10% of a university's publications will belong to the 10% most-highly cited papers in the reference group. A university that publishes more than 10% of these top papers scores above expectation. The z -test can be used to test the significance of the observed number of papers in the top 10% segment against the expected 10%. In addition to comparing a university with the expectation, the test can be applied to the differences between any two universities. A value of $z = 1.96$ indicates a significance of the difference at the 5% level: $z > 2.576$ indicates that the chance process is only 1 in 100, and for $z > 3.29$, the chance rate is only one *per mille*. A negative z -score indicates *mutatis mutandis* that the score is *below* expectation. The resulting z values can be compared and used for ranking purposes.

It can be derived from Eq.1 that the test statistics between two proportions—percentages are proportions—can be formulated as follows (Sheskin, 2011):

$$z = \frac{p_1 - p_2}{\sqrt{p(1-p) \left[\frac{1}{n_1} + \frac{1}{n_2} \right]}} \quad (2)$$

where n_1 and n_2 are the numbers of all the papers published by institutions 1 and 2 (under the column “ P ” in the LR); and p_1 and p_2 are the values of $PP_{top\ 10\%}$ of institutions 1 and 2. The pooled estimate for proportion p is defined as:

$$p = \frac{t_1 + t_2}{n_1 + n_2} \quad (3)$$

where: t_1 and t_2 are the numbers of top 10% papers of institutions 1 and 2. These numbers can be calculated on the basis of the values for “ P ” and “ $PP_{top\ 10\%}$ ” in LR. When testing values for a single university, $n_1 = n_2$, p_1 is the value of the $PP_{top\ 10\%}$, $p_2 = 0.1$, and $t_2 = 0.1 * n_2$ (that is, the expected number in the top 10%).

Using the same numerical example as above, $n_1 = 19,902$ for Tsinghua and $n_2 = 23,510$ for Zhejiang, respectively; $t_1 = 2738$ and $t_2 = 2604$ (Table 2a). The pooled estimate p is in this case:

$$p = \frac{2738 + 2604}{19902 + 23510} = \frac{5342}{43412} = 0.123054$$

$$p(1-p) = 0.1234 * 0.8766 = 0.1081$$

Using Eq. 2, one can fill out as follows:

$$z = \frac{\frac{13.8 - 11.1}{100}}{\sqrt{0.1081 \left[\frac{1}{19,902} + \frac{1}{23,510} \right]}} = 8.525$$

The z -test indicates that the scores of these two universities are statistically different above the 0.001 level.

It can be shown that if both the z -test and the chi-square are applied to the same set of data, the square of the z -value is equal to the chi-square value (Sheshkin, 2011). The residuals to the chi-square are standardized as a z -statistics as well. The z -test for two independent proportions (e.g. percentages) provides an alternative large-samples procedure for evaluating contingency tables. The z -test is the most appropriate test given the research questions and the design (Sheshkin, 2011).[®]

3.4 Confidence intervals

The LR additionally provides confidence intervals[®] which can be used as another statistic for grouping universities.[®] When the confidence intervals of two universities overlap, the distinction between them can be ignored in terms of the indicator (e.g. Colliander & Ahlgren, 2011). The words confidence and stability intervals can be used interchangeably.

Since each of two universities may be indistinguishable from other universities, one thus obtains a so-called “weak” component in terms of network analysis. If both the upper and lower bounds of university A are contained within the stability interval of university B, the performance of the former can be seen as similar to the latter; network analysis would place them into the same cluster. In this case, we have a strong component since both arcs are valued.

Using the same example of comparing Tsinghua with Zhejiang, Figure 1 shows that there is no overlap between their confidence intervals. This accords with our

[®] At <http://www.leydesdorff.net/leiden11/index.htm> the user can retrieve a file *leiden11.xls* which allows for feeding values harvested from the LR for the comparison of any two universities. The effect sizes are additionally provided in the template.

[®] The confidence intervals are based on bootstrapping; that is, random drawings that are sufficiently repeated to provide stable patterns. In case of the LR, one draws thousand times a sample from each university's set of publications. In order to obtain a 95% stability interval, the lower and upper bounds of the stability intervals are taken as the 2.5th and the 97.5th percentiles of the thus generated distribution of $PP_{top\ 10\%}$ values (Waltman et al., 2012).

[®] Bornmann and Leydesdorff's (2013) analysis of LR 2011 compared the stability intervals with other possible ways to calculate standard errors (e.g. the standard errors of a binary probability). They found a perfect correlation between stability intervals and these other possible ways which are based on less data-intensive computing procedures.

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previous conclusion that the output of these two universities in terms of *PP-top10%* is significantly different. For didactic reasons, we added Peking University to the comparison in Figure 1 and Table 7 so that we can draw Figure 2 with the *z*-values as a further illustration of the options for visualization.

Figure 1. Potentially overlapping confidence intervals of the PP-Top10% for three leading Chinese universities.

Zhejiang and Peking University both have a lower bound of 10.5% of top 10% articles. The upper bound of Zhejiang, however, is higher than for Peking University. Table 5 shows the *z*-values for these three nodes on the main diagonal and the links off-diagonal. The *z*-values are also written into Figure 2.

Table 5. *z*-values for nodes and links among three leading Chinese universities.

	Peking University	Tsinghua University	Zhejiang University
Peking University	2.689 **		
Tsinghua Univ.	8.460 ***	11.005 ***	
Zhejiang University	0.638	8.533 ***	3.800 ***

Significance levels: * *p* < .05; ** *p* < .01; *** *p* < .001

The difference between Peking and Zhejiang University is *not significant*, leading to an arc between these two universities (*z* = 0.64) in Figure 2 and placing them into a cluster together. This weak component does not include Tsinghua University which scores significantly different on this performance indicator (PP-Top10%).

Figure 2. Grouping of significantly different and non-different values for *PP*-top10% among three Chinese universities; *z*-values (provided in the figure) are used for sizing the nodes.

4 Results

4.1 Results based on using the *z*-test

Aggregating universities into networked groups based upon their *z*-score similarities creates clusters. Figure 3 shows the resulting clusters among 205 Chinese universities. The *z*-values are used as input to the sizes of the nodes and fonts, and the *z*-values between two universities determine the lines insofar as $z < 2.576$ ($p < .001$) since universities which are not significantly different, are considered as part of the same group. Note that this grouping is on the basis of (structural) similarity and not on actions. We use VOSviewer only for the layout and visualization. The grouping is based on the above statistics. The file is first organized as partitions in Pajek which are exported to VOSviewer. We chose this procedure in order to prevent parameters in VOSviewer (e.g., resolution) to affect the grouping. (In other words, the clustering is not updated in VOSviewer.)

Three major groups of universities and two isolates are distinguished in the analysis and shown in Figure 3: A top-group of 32 universities is listed in Table 9 (Appendix). As could be expected, Tsinghua leads this group with a *z*-score of 11.0, followed by Hunan University ($z = 10.2$).

The second group of 69 universities is headed by Zhejiang University and listed in Table 10 (Appendix). As shown above, Peking University is not significantly different from Zhejiang University; it is ranked in the 24th position overall but, following Zhejiang, Peking University is in the 5th position within the second group. Only the top 30 (43.5%) of these 69 universities score on the *PP*-10% above expectation. A third group of 102 universities are listed in Table 11 (Appendix). None of these universities score above expectation.

Figure 3: Grouping of 205 Chinese universities in terms of z -values ($p < 0.1$), VOSviewer used only for the visualization; modularity $Q = 0.165$. The figure can be web-started from [here](#) (or with a black background from [here](#)).

Two universities—Chang'an and Shanxi—form a fourth cluster with both negative z -values. Table 6 provides the top 20 universities in each of the three groups in decreasing order (on the basis of the z -values). Note that five of the 20 universities listed on the top-list are from an address in Hong Kong, China.

The results are sometimes counterintuitive. However, Brewer, Gates, & Goldman (2001) drew attention to the difference between prestige and reputation; prestige is sticky, whereas the citation windows are only four years in LR. For example, Fudan University is considered a prestigious university in China. In the period under study, however, Fudan was listed as an address in 15,442 papers in journals included in the ISI-list. Only 1,395 of these papers (or 9.0%) belonged to the top 10% most-cited papers. This profile is not significantly different from other universities in the third group.

The reason for this relatively low rank of Fudan University is not a decline of publications with this university among the addresses, but a relative decline of papers in the top 10% in this university's publications. The number of publications with Fudan University among the author-addresses shows an increase of 1,127 papers over the consecutive four-year periods and on the basis of fractional counting (Figure 4). However, the yearly increase in the number of publications in the top 10% segment is only 6.9% (775 papers/year). The relative decline can be cumulative as a composed interest rate (Figure 4). It may be caused by all kind of effects in the data or in the model. *Ceteris paribus*, for example, an increase in fractional counting leads to a decline in the share of publications and citations (e.g. Anderson et al., 1988).

Mutatis mutandis, one can be puzzled by the high status of Shandong University of Science and Technology at the sixth position and Qufu Normal University at the 13th on the top-list. Shandong University published 1,576 articles during the period under study, of which 299 belong to the top 10%. This is almost 19% and thus far exceeds the expectation of 10%. Further analysis may enable us to understand these counterintuitive results.

4.2 Results based on confidence intervals

Figure 5 provides the resulting figure using the overlaps in confidence levels for the delineation of groups: 75 universities are classified as top-universities. These universities are listed in Table 12 (Appendix).

A measure for the correspondence between the two classifications—the one above based on z -scores (Figure 2) and this one (Figure 5)—is provided by Cramér's V , which is based on chi-square statistics, but which conveniently varies between

Table 6. Top-20 universities in each of the three clusters. (See for a full list in the Annexes.)

	top group (top 20)	z	middle group (top 20)	z	bottom group (top 20)	z
1	Tsinghua Univ.	11.005	Zhejiang Univ.	3.800	Hubei Univ.	-0.498
2	Hunan Univ.	10.193	Harbin Institute of Technology	3.226	Northwest Univ.	-1.609
3	Hong Kong Univ. of Science and Technology	6.566	Huazhong Univ. of Science and Technology	2.907	South China Agricultural Univ.	-1.631
4	Univ. of Science and Technology of China	6.482	Peking Univ.	2.689	Zhejiang Univ. of Technology	-1.676
5	City Univ. of Hong Kong	6.454	Nanjing Univ.	1.973	China Univ. of Mining and Technology	-1.678
6	Shandong Univ. of Science and Technology	6.444	Xiamen Univ.	1.954	Nanjing Univ. of Aeronautics and Astronautics	-1.816
7	Hong Kong Polytechnic Univ.	6.406	Wuhan Univ.	1.765	Second Military Medical Univ.	-1.844
8	South China Univ. of Technology	6.049	Tianjin Univ.	1.738	Zhejiang Sci-Tech Univ.	-1.886
9	Chinese Univ. of Hong Kong	5.993	Dalian Univ. of Technology	1.553	Taiyuan Univ. of Technology	-1.934
10	Nankai Univ.	4.860	East China Normal Univ.	1.333	Shanghai Univ. of Traditional Chinese Medicine	-1.950
11	Univ. of Hong Kong	4.418	Soochow Univ.	1.310	Qingdao Univ. of Science and Technology	-1.961
12	Shenzhen Univ.	4.089	Univ. of Electronic Science and Technology of China	1.154	Nanjing Univ. of Chinese Medicine	-1.981
13	Qufu Normal Univ.	3.724	Nanjing Univ. of Science and Technology	1.140	Harbin Engineering Univ.	-2.033
14	Fuzhou Univ.	3.487	Southwest Jiaotong Univ.	1.088	Lanzhou Univ.	-2.110
15	Beihang Univ.	3.432	China Univ. of Geosciences	1.035	Northeast Normal Univ.	-2.128
16	Univ. of the Chinese Academy of Sciences	3.354	Huazhong Agricultural Univ.	1.030	China Jiliang Univ.	-2.130
17	Central China Normal Univ.	3.090	Tongji Univ.	0.954	Jiangnan Univ.	-2.163
18	Univ. of Macau	3.046	Univ. of Science and Technology Beijing	0.932	Jinan Univ.	-2.227
19	Northwestern Polytechnical Univ.	2.915	China Agricultural Univ.	0.704	Hangzhou Normal Univ.	-2.245
20	Wuhan Univ. of Technology	2.914	Beijing Institute of Technology	0.587	Southern Medical Univ.	-2.263

Figure 4. Development of the values of P , $P\text{-top}10\%$, and $PP\text{-Top}10\%$ for Fudan University during 2016–2020.

0 and 1. Cramèr's V between these two classifications is significant ($V = 0.48$; $p < 0.01$).[®]

5 Comparison among Chinese and American universities

In the LR2020, universities are grouped by nation-states, but it is possible to draw samples of universities across nations or within nations. Classification of universities at lower levels of aggregation can be relevant for the study of regional innovation systems. Whereas universities remain the units of analysis in LR, relevant samples can be drawn from the database on the basis of a specific research question.

For example, if the research question is about comparing universities in the EU, one can study the EU as a single unit internally different from the USA or China. The organization at the level of EU is probably different from the sum of the national perspectives. As noted, LR also contains information for six major fields so that one can cross-tabulate nations with these disciplinary categories, where one could test

[®] An alternative measure is phi; $\phi = 0.831$ ($p < 0.01$). The Spearman rank-order correlation between the clustering based on the two methods is .6 ($p < 0.01$).

Figure 5 Grouping of 205 Chinese universities based on overlapping confidence intervals; VOSviewer used for the decomposition and clustering; font- and node-sizes based on z-values. (The map can be web-started from [here](#).)

Figure 6 Grouping of 205 Chinese and 197 US universities in terms of z-values; differences among groups are significant at the 1% level; VOSviewer used for the decomposition and clustering. (The map can be web-started from [here](#).)

in principle the conjecture that “China is strong in the basic sciences and the US in the biomedical sciences.” We will leave this for a later study, but focus here first on how to compare US and Chinese universities in a single framework.

Both the US and China happen to be represented with approximately 200 universities in LR 2020 (Table 8). Among the 198 American universities, Rockefeller University is an extreme outlier with more than 30% of the papers in the top 10% most-highly cited group. The following analysis is based on 205 Chinese and $(198 - 1 \text{ (Rockefeller University)}) = 197$ American universities. The clustering in the network among these $(197 + 205 =) 402$ universities is visualized in Figure 6. Three clusters and a few isolates are distinguished by the statistical analysis. The isolates are: George Mason University and the University of Toledo in the USA, and the Hangzhou Dianzi University in China. The cross-tabulation in Table 7 is significant at the one-percent level ($\chi^2 = 93.40$; $p < .01$).

Table 7. Descriptive statistics of the comparison among 197 American and 205 Chinese universities.

Row Labels	low	middle	High	Isolates	Grand Total
China	116	67	21	1	205
USA	36	60	99	2	197
Grand Total	152	127	120		402

Table 8 shows the top 20 Chinese universities juxtaposed to the 20 American universities with highest z -scores at different scales. This table reveals that the highest ranked among the Chinese universities (Tsinghua with $z = 11.005$) does not reach the z -level of the lowest among the 20 most-highly ranked American universities in the right column ($z = 12.23$). This may be due in part to historical factors where Chinese authors are not as well integrated into the network of science as others and thus struggle to gain citations, and it may also reflect some quality issues, as well. Figure 7 shows that the distribution of z -scores is systematically lower for Chinese universities than for their US counterparts. In other words, using these parameters, China is still far behind the US in terms of the quality of its universities.

6 Dynamic effects of changes in the model

The methodology for the normalization in terms of different fields of science is continuously improved by CWTS and the database is expanded with new universities. In LR 2016, for example, the number of universities covered was 842 compared to 1,076 in this study based on LR2020. The expansion of the database from year to year may have an effect on the rankings because universities may enter the comparison with higher or lower scores on the relevant parameter.

Table 8. Highest ranked universities in top-groups in the combined American-Chinese set of 402 universities in LR 2020 with their respective z-scores.

rank	Top 20 Chinese universities	z	Top 20 American Universities	z
1	Tsinghua Univ.	11.005	Harvard Univ.	36.632
2	Hunan Univ.	10.193	Stanford Univ.	26.028
3	Hong Kong Univ. of Science and Technology	6.566	Massachusetts Institute of Technology	24.504
4	Univ. of Science and Technology of China	6.482	Univ. of California, Berkeley	20.319
5	City Univ. of Hong Kong	6.454	Yale Univ.	16.576
6	Shandong Univ. of Science and Technology	6.444	Univ. of California, San Francisco	16.524
7	Hong Kong Polytechnic Univ.	6.406	Princeton Univ.	16.522
8	South China Univ. of Technology	6.049	Columbia Univ.	16.348
9	Chinese Univ. of Hong Kong	5.993	Univ. of California, San Diego	16.061
10	Nankai Univ.	4.860	Univ. of Pennsylvania	15.975
11	Univ. of Hong Kong	4.418	Cornell Univ.	14.934
12	Shenzhen Univ.	4.089	Univ. of Washington, Seattle	14.620
13	Qufu Normal Univ.	3.724	Johns Hopkins Univ.	14.540
14	Fuzhou Univ.	3.487	Northwestern Univ.	14.488
15	Central China Normal Univ.	3.090	Univ. of California, Los Angeles	14.450
16	Univ. of Macau	3.046	Univ. of Michigan	13.951
17	Wuhan Univ. of Technology	2.914	California Institute of Technology	13.695
18	Southern Univ. of Science and Technology	2.332	Univ. of Chicago	13.561
19	GuangZhou Univ.	2.120	Duke Univ.	12.605
20	Hong Kong Baptist Univ.	2.094	Washington Univ. in St. Louis	12.123

Figure 7. Distribution of z values in decreasing order for 205 Chinese and 197 American universities.

To address the problem of changes in the methodology, LR values are recalculated each year for the historical values of the indicators based on the latest methodology. Thus, we have two time series: one based on the yearly series of LR 2016 to LR2020 and one based on the reconstruction of the data using the method of LR 2020. The two series for Fudan university are graphed in Figure 8.

Figure 8. The participation of Fudan University in the top 10% class of papers using the Leiden Rankings for subsequent years as a time series *versus* the reconstruction using the 2020-model.

In LR 2016, Fudan University had 9.81% of its papers in the top 10% class (all fields). In 2020, the position of Fudan University has dropped to 9.03 % of its papers in the top 10% class. This is a decline of 0.78% (9.81–9.03). Would Fudan University have been able to keep the value of 9.81%, it would still have been in the second tier in 2020. Using the 2020 model, however, the value for 2016 is reconstructed as 9.54%, so that we can conclude that the difference in the data is only 0.37% (that is, 9.81–9.54%). The remaining decline (9.54–9.03 =) 0.51% is an effect of changes in the model. In other words, the model accounts for almost two-thirds of the decline ($0.51/0.78 = 65.4\%$) and the citation data themselves for ($0.27/0.78 =$) 34.6%. These relative declines are of the same order of magnitude as the ones shown in Leydesdorff, Wouters, and Bornmann (2017) for Carnegie Mellon University in the USA during the period 2012–2016.

7 Discussion and conclusions

In summary, both changes in the data and changes in the model can result in differences in the rankings. Whereas scientometric indicators are meant to serve “objectivization” of the discussion about quality, the quality of the indicators themselves is also an issue in the discussion of the results which requires attention. Differences may be due to changes in the data, the models, or the modeling effects on the data.

Our main argument has been that differences among universities can be tested for their statistical significance. This allows for a classification, since universities which are not significantly different can be grouped together, regardless of geographic location. The scientometric groupings, however, should not be reified. The groupings are not stable when we use different methods. Particularly at the margins, the attribution may be sensitive to parameter choices.

The statistics relativize the values of decimals in the rankings. One can operate with a scheme of low/middle/high in policy debates and leave the more fine-grained rankings of individual universities to operational management and local settings. Further analysis can reveal points which merit attention and discussion. Is a decline due to a parameter choice, or is there a reason for concern? An alternative view can foreground unseen relationships in the background; the resulting insights can be made the subject of managerial and political interventions. One can expect that qualitative assessments lag behind the ongoing developments. Cultural expectations are conservative, while all universities are under the pressure to change their position in relationship to one another in a competitive environment. One can zoom in and organize follow-up investigations in these cases. The result may initially be unwelcome, but can also induce asking urgent questions.

At the macro level, our results show that Chinese universities do not yet (?) operate at the same levels of performance as those in the USA. Despite concerns in

the US about the “competition” from Chinese universities, the latter do not rank in the same elite categories as American universities at this time. As in other national systems, we found three or four groups of universities at national levels. In the case of China, the top-list includes five universities with an address in Hong Kong, perhaps partly because of the historical British tradition operating in the background.

8 Normative implications

University ranking services contribute to the hierarchy of reputation and status that has been the subject of critique and scholarship. Bourdieu (1998) examined the political, intellectual, bureaucratic, and economic forms of power that influence governance and the allocation of resources based upon elite reputation, claiming a link among them. This line of scholarship views international status and side-by-side comparisons, such as those found in rankings, as operating within a framework of broader geopolitical struggles (Heilbron, Boncourt, & Sorá, 2018). From this perspective, placing Chinese universities into international rankings is a political act rather than simply social science. Rankings, then, become an artifact of globalization reflecting political posturing.

It is important to tread lightly here because a vast literature is available addressing globalization. Certainly, Chinese universities are actively widening the scope of cross-border communication, intensifying transnational mobility, and, apparently, growing dependency on global structures—all features of globalization. Further, geopolitical power struggles may be served in different ways by rankings and their underlying assumptions, such as ones that present China’s universities as challenging those of the West for preeminence in knowledge creation for competitiveness or military hegemony. The rankings can also be considered as instantiating an unequal distribution of power that are at the root of asymmetrical power relations. These measures of symmetry or asymmetry, elite status, or reputation, then become important to challenge from several angles, of which we addressed one here.

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Author contributions

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Appendix

Table 9. Top group of 32 Chinese universities.

University	Z	overall rank	within-group rank
Tsinghua University	11.005	1	1
Hunan University	10.193	2	2
Hong Kong University of Science and Technology	6.566	3	3
University of Science and Technology of China	6.482	4	4
City University of Hong Kong	6.454	5	5
Shandong University of Science and Technology	6.444	6	6
Hong Kong Polytechnic University	6.406	7	7
South China University of Technology	6.049	8	8
Chinese University of Hong Kong	5.993	9	9
Nankai University	4.860	10	10
University of Hong Kong	4.418	11	11
Shenzhen University	4.089	12	12
Qufu Normal University	3.724	14	13
Fuzhou University	3.487	15	14
Beihang University	3.432	16	15
University of the Chinese Academy of Sciences	3.354	17	16
Central China Normal University	3.090	19	17
University of Macau	3.046	20	18
Northwestern Polytechnical University	2.915	21	19
Wuhan University of Technology	2.914	22	20
Southern University of Science and Technology	2.332	25	21
Beijing University of Chemical Technology	2.273	26	22
GuangZhou University	2.120	27	23
Hong Kong Baptist University	2.094	28	24
Shandong Normal University	1.478	34	25
Jiangsu Normal University	1.313	36	26
Zhejiang Normal University	1.238	38	27
University of Jinan	1.195	39	28
Nanjing University of Information Science and Technology	1.093	42	29
Hangzhou Dianzi University	0.449	51	30
Heilongjiang University	-0.158	62	31
Qingdao Agricultural University	-0.422	67	32

Table 10. Middle group of 69 Chinese universities.

University	z	overall rank	within-group
Zhejiang University	3.800	13	1
Harbin Institute of Technology	3.226	18	2
Huazhong University of Science and Technology	2.907	23	3
Peking University	2.689	24	4
Nanjing University	1.973	29	5
Xiamen University	1.954	30	6
Wuhan University	1.765	31	7
Tianjin University	1.738	32	8
Dalian University of Technology	1.553	33	9
East China Normal University	1.333	35	10

University	z	overall rank	within-group
Soochow University	1.310	37	11
University of Electronic Science and Technology of China	1.154	40	12
Nanjing University of Science and Technology	1.140	41	13
Southwest Jiaotong University	1.088	43	14
China University of Geosciences	1.035	44	15
Huazhong Agricultural University	1.030	45	16
Tongji University	0.954	46	17
University of Science and Technology Beijing	0.932	47	18
China Agricultural University	0.704	48	19
Beijing Institute of Technology	0.587	49	20
Sun Yat-sen University	0.572	50	21
North China Electric Power University	0.414	52	22
China University of Petroleum Beijing	0.389	53	23
Guangdong University of Technology	0.332	54	24
Shanghai University	0.332	55	25
Fourth Military Medical University	0.257	56	26
Beijing Normal University	0.178	57	27
Chongqing University	0.000	58	28
Hefei University of Technology	0.000	59	29
Xi'an Jiaotong University	0.000	60	30
Nanjing University of Posts and Telecommunications	-0.110	61	31
Nanjing Agricultural University	-0.171	63	32
China Pharmaceutical University	-0.259	64	33
Central South University	-0.280	65	34
China University of Petroleum East China	-0.407	66	35
Beijing Jiaotong University	-0.448	68	36
Xidian University	-0.529	71	37
Dalian Medical University	-0.643	72	38
Chongqing University of Posts and Telecommunications	-0.656	73	39
Huaqiao University	-0.795	74	40
Anhui Agricultural University	-0.862	75	41
Wuhan University of Science and Technology	-0.899	76	42
Nanjing Tech University	-0.919	77	43
Donghua University	-0.923	78	44
East China University of Science and Technology	-0.943	79	45
Army Medical University	-0.952	80	46
Anhui University	-1.004	81	47
Tianjin University of Technology	-1.047	82	48
Renmin University of China	-1.064	83	49
Nanjing Normal University	-1.189	84	50
Southeast University	-1.213	85	51
Fujian Agriculture and Forestry University	-1.218	86	52
Northwest Agriculture and Forestry University	-1.226	87	53
University of Shanghai for Science and Technology	-1.232	88	54
North China University of Science and Technology	-1.249	89	55
Wenzhou University	-1.306	90	56
Southwest Petroleum University	-1.311	91	57
Shaanxi University of Science and Technology	-1.314	92	58
China Three Gorges University	-1.333	93	59
University of South China	-1.345	94	60
Shanghai Normal University	-1.369	95	61
Dalian Maritime University	-1.380	96	62

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University	z	overall rank	within-group
Yangzhou University	-1.392	97	63
Changzhou University	-1.544	98	64
Nanjing Forestry University	-1.581	99	65
Guangzhou University of Chinese Medicine	-1.685	104	66
Fujian Normal University	-1.781	105	67
China Academy of Chinese Medical Sciences	-1.840	107	68
Shanghai Jiao Tong University	-1.876	109	69

Table 11. Bottom group of 102 Chinese universities.

University	z	rank	within-group
Hubei University	-0.498	70	1
Northwest University	-1.609	100	2
South China Agricultural University	-1.631	101	3
Zhejiang University of Technology	-1.676	102	4
China University of Mining and Technology	-1.678	103	5
Nanjing University of Aeronautics and Astronautics	-1.816	106	6
Second Military Medical University	-1.844	108	7
Zhejiang Sci-Tech University	-1.886	110	8
Taiyuan University of Technology	-1.934	111	9
Shanghai University of Traditional Chinese Medicine	-1.950	112	10
Qingdao University of Science and Technology	-1.961	113	11
Nanjing University of Chinese Medicine	-1.981	114	12
Harbin Engineering University	-2.033	115	13
Lanzhou University	-2.110	117	14
Northeast Normal University	-2.128	118	15
China Jiliang University	-2.130	119	16
Jiangnan University	-2.163	120	17
Jinan University	-2.227	121	18
Hangzhou Normal University	-2.245	122	19
Southern Medical University	-2.263	123	20
Hunan Normal University	-2.282	124	21
Henan University	-2.328	125	22
Beijing University of Chinese Medicine	-2.346	126	23
Tianjin Medical University	-2.348	127	24
Shantou University	-2.383	128	25
Xi'an University of Architecture and Technology	-2.384	129	26
Hainan University	-2.417	130	27
Hohai University	-2.453	131	28
Beijing University of Posts and Telecommunications	-2.458	132	29
Qingdao University	-2.465	133	30
Jiangsu University	-2.467	134	31
Jiangxi Normal University	-2.486	135	32
Shaanxi Normal University	-2.505	136	33
Shandong University of Technology	-2.506	137	34
Nanchang University	-2.528	138	35
Henan Agricultural University	-2.584	139	36
Guizhou University	-2.675	140	37
Guangxi Normal University	-2.709	141	38
Northeast Forestry University	-2.751	142	39
Northeastern University	-2.761	143	40

University	z	rank	within-group
Henan Normal University	-2.775	144	41
Shandong Agricultural University	-2.783	145	42
Anhui Normal University	-2.834	146	43
Lanzhou University of Technology	-2.835	147	44
Ningbo University	-2.838	148	45
Southwest University	-2.855	149	46
Yunnan University	-2.940	150	47
Shanghai Ocean University	-2.954	151	48
Northwest Normal University	-2.962	152	49
Inner Mongolia University	-2.968	153	50
Beijing University of Technology	-2.969	154	51
Fudan University	-3.065	155	52
Yanshan University	-3.100	156	53
Tianjin University of Science and Technology	-3.150	157	54
Beijing Forestry University	-3.151	158	55
People's Liberation Army University of Science and Technology	-3.152	159	56
Capital Normal University	-3.188	160	57
Southwest University of Science and Technology	-3.433	161	58
Hebei University of Technology	-3.558	162	59
Shenyang Pharmaceutical University	-3.713	163	60
Xinjiang University	-3.741	164	61
Kunming University of Science and Technology	-3.832	165	62
Nantong University	-3.935	166	63
Xiangtan University	-4.012	167	64
Northeast Agricultural University	-4.025	168	65
Wenzhou Medical University	-4.062	169	66
Chongqing Medical University	-4.106	170	67
Guangxi University	-4.119	171	68
Xi'an University of Technology	-4.203	172	69
Zhengzhou University	-4.244	173	70
Ocean University of China	-4.246	174	71
Henan Polytechnic University	-4.348	175	72
Shihezi University	-4.400	176	73
Kunming Medical University	-4.506	177	74
Xuzhou Medical College	-4.604	178	75
Tianjin Polytechnic University	-4.775	179	76
South China Normal University	-4.827	180	77
Nanjing Medical University	-4.941	181	78
Chengdu University of Technology	-4.958	182	79
Xinxiang Medical University	-4.962	183	80
Harbin University of Science and Technology	-5.001	184	81
North University of China	-5.068	185	82
Yangtze University	-5.093	186	83
Guangzhou Medical University	-5.200	187	84
Sichuan Agricultural University	-5.212	188	85
Sichuan University	-5.247	189	86
National University of Defense Technology	-5.257	190	87
Harbin Medical University	-5.331	191	88
Tianjin Normal University	-5.358	192	89
Shanxi Medical University	-5.378	193	90
Henan University of Science and Technology	-5.416	194	91
Shandong University	-5.619	195	92

Research Paper

University	z	rank	within-group
Anhui Medical University	-5.951	196	93
Hebei University	-6.307	197	94
Guangxi Medical University	-7.267	198	95
Peking Union Medical College	-7.621	199	96
Xinjiang Medical University	-7.703	200	97
China Medical University	-8.064	201	98
Fujian Medical University	-8.169	202	99
Hebei Medical University	-8.966	203	100
Jilin University	-9.607	204	101
Capital Medical University	-12.944	205	102

Table 12. 75 top universities with overlapping confidence values.

University	Z	rank	within group
Tsinghua University	11.005	1	1
Hunan University	10.193	2	2
Hong Kong University of Science and Technology	6.566	3	3
University of Science and Technology of China	6.482	4	4
City University of Hong Kong	6.454	5	5
Shandong University of Science and Technology	6.444	6	6
Hong Kong Polytechnic University	6.406	7	7
South China University of Technology	6.049	8	8
Chinese University of Hong Kong	5.993	9	9
Nankai University	4.860	10	10
University of Hong Kong	4.418	11	11
Shenzhen University	4.089	12	12
Zhejiang University	3.800	13	13
Qufu Normal University	3.724	14	14
Fuzhou University	3.487	15	15
Beihang University	3.432	16	16
University of the Chinese Academy of Sciences	3.354	17	17
Harbin Institute of Technology	3.226	18	18
Central China Normal University	3.090	19	19
University of Macau	3.046	20	20
Northwestern Polytechnical University	2.915	21	21
Wuhan University of Technology	2.914	22	22
Huazhong University of Science and Technology	2.907	23	23
Peking University	2.689	24	24
Southern University of Science and Technology	2.332	25	25
Beijing University of Chemical Technology	2.273	26	26
GuangZhou University	2.120	27	27
Hong Kong Baptist University	2.094	28	28
Nanjing University	1.973	29	29
Xiamen University	1.954	30	30
Wuhan University	1.765	31	31
Tianjin University	1.738	32	32
Dalian University of Technology	1.553	33	33
Shandong Normal University	1.478	34	34
East China Normal University	1.333	35	35
Jiangsu Normal University	1.313	36	36
Soochow University	1.310	37	37

University	Z	rank	within group
Zhejiang Normal University	1.238	38	38
University of Jinan	1.195	39	39
University of Electronic Science and Technology of China	1.154	40	40
Nanjing University of Science and Technology	1.140	41	41
Nanjing University of Information Science and Technology	1.093	42	42
Southwest Jiaotong University	1.088	43	43
China University of Geosciences	1.035	44	44
Huazhong Agricultural University	1.030	45	45
Tongji University	0.954	46	46
University of Science and Technology Beijing	0.932	47	47
China Agricultural University	0.704	48	48
Beijing Institute of Technology	0.587	49	49
Sun Yat-sen University	0.572	50	50
Hangzhou Dianzi University	0.449	51	51
North China Electric Power University	0.414	52	52
China University of Petroleum Beijing	0.389	53	53
Guangdong University of Technology	0.332	54	54
Shanghai University	0.332	55	55
Fourth Military Medical University	0.257	56	56
Beijing Normal University	0.178	57	57
Chongqing University	0.000	58	58
Hefei University of Technology	0.000	59	59
Xi'an Jiaotong University	0.000	60	60
Nanjing University of Posts and Telecommunications	-0.110	61	61
Heilongjiang University	-0.158	62	62
Nanjing Agricultural University	-0.171	63	63
China Pharmaceutical University	-0.259	64	64
Central South University	-0.280	65	65
China University of Petroleum East China	-0.407	66	66
Qingdao Agricultural University	-0.422	67	67
Beijing Jiaotong University	-0.448	68	68
Chang'an University	-0.465	69	69
Hubei University	-0.498	70	70
Dalian Medical University	-0.643	72	71
Chongqing University of Posts and Telecommunications	-0.656	73	72
Huaqiao University	-0.795	74	73
Anhui Agricultural University	-0.862	75	74
Army Medical University	-0.952	80	75