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Comprehensive quantitative analysis of TOP-100s of ARWU, QS and THE World University Rankings for 2014–2018

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The article examines the global university reputation race, launched in 2003. Between 2003 and 2010, there appeared a cluster of publications on the qualitative comparative analysis of their methodologies, and since 2010, a cluster of publications on the quantitative comparative analysis of university rankings has started to form. The review made it possible to identify a number of unsolved problems concerning the stability of university rankings, aggregation of the number of universities and their Overall Scores (Total Scores) by country in various rankings. Our study aimed at solving these tasks was carried out for TOP-100s of ARWU, QS, and THE rankings. When calculating the fluctuation range of the university rankings, the top twenty of the most stable and most unstable university rankings were identified in the rankings under study. The best values of the aggregated indicators by the number of universities and the Overall Scores were identified for the USA and the UK.

Keywords: World University Rankings, comparative quantitative analysis, university reputation race, Overall Score, Total Score, ranking stability

1. Introduction

The essence of the university ranking race in the globalization era was well described by Hazelkorn (2015, 1): "There is growing obsession with university rankings around the world. What started as an academic exercise in early 20th century in the US became commercial "information" service for students in the 1980s and the progenitor of a "reputation race" with geo-political implications today." What a burden it imposes on national higher education and science systems, as well as on taxpayers, was described earlier (Moskovkin et al., 2016a, 2016b).

Soh (2012) claimed that over a decade the university ranking has become ritualistic in higher education, with rankers, rank users and their intermediaries acting through mass media representing their annual ritual. Though this ritual looks irrational to

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intellectuals, it is quite acceptable for society, as in the globalized world all realms of life are obsessed with all sorts of rankings.

Despite the on-going criticism of global university rankings (Marginson, 2007; Saisana et al., 2011; Soh, 2012, 2017), they have long become very influential tools, with a strong influence on decision-making in the academic community and on the structure of its institutions (Hazelkorn, 2007, 2008). The number of rankings is constantly growing, with politicians (Salmi, 2009), employers (Tofallis, 2012), recruiters (Harvey, 2008), students (Clarke, 2007; Cebolla-Boado et al., 2018) and, of course, university management (Hazelkorn, 2007; Salmi, 2009) using their results.

The global interest to "university reputation race" and "university religious rituals" resulted in creating a number of world university rankings. Each of the rankings fueled reputation or publication race in certain regions, and globally. At the moment, there are 13 of such rankings: ARWU (Shanghai, China, 2003); THE WUR (UK, 2004); QS WUR (UK, 2004); Webometrics (Spain, 2004); NTU Ranking (Taiwan, 2007); CWTS Leiden Ranking (Netherlands, 2007); SCimago Institution Ranking (SIR) (Spain, 2009); URAP (Turkey, 2010); CWUR (Saudi Arabia, 2012); Round University Ranking (RUR) (Russia, 2013); US NEWS Ranking (USA, 2014); U-multirank (EU, 2014); and MosIUR (Russia, 2017) (launch year for each ranking is shown in brackets).

A large number of World University Rankings has made it important to carry out their comparative analysis, first, qualitative and then quantitative. This paper describes a quantitative comparative analysis of such rankings in order to study their structural dynamics, mobility, and stability over time.

2. Literature review

The essence of "the reputation race", among other things, shows in the fact that some ranking agencies publish their rankings in the middle of the current year, claiming them to be the current-year or even next-year rankings, though it would have been logical to expect the results of the year either by the end of the current year, or at the beginning of the following year. This referes to such rankings as QS, THE, URAP, and CWUR. All these facts make a comparative analysis of the World University Rankings more difficult. When Mussard and James (2018) wanted to have a cross-correlation analysis of the parameters of some universities ranked by three ranking agencies in 2016, they had to use the results of QS WUR 2018, THE WUR 2017–2018, and ARWU 2017.

A number of authors are quite critical of World University Rankings, most criticism coming due to inability to compare the universities so different in their missions and features, subjective choice of individual indicators and their weights. The most profound analysis of such criticism was carried out in (Soh, 2012; Soh, 2013a, 2013b), in which Soh for the first time noticed "Simpson's paradox and confounding factors in university rankings and the ill effects of discrepancies between nominal

and attained weights" (Soh, 2012). Further Soh (2017) wrote about all seven sins of World University Rankings.

It is only natural that a number of various World University Rankings resulted in their comparative analysis. At first, according to Shehata and Mahmood (2016), there appeared a large cluster of papers on qualitative comparative analysis of the ranking methodologies, followed by a cluster of publications on their quantitative comparative analysis with the focus on Pearson's/Spearman's correlations and overlapping.

A review of the second cluster of the publications is usually started with Aguillo at al. (2010). By the time of data collection for that paper (late-2008), as can be seen from our list of rankings, five World University Rankings had been launched, which were used for the above-mentioned paper, but, as CWTS Leiden Ranking ranked only European universities, it was excluded from the further analysis.

Aguillo et al. (2010) used three rank-order similarity measures to study the correlation among the 2008 results of four World University Rankings, namely, ARWU, THE-QS, WR (Webometrics), and HEEACT. The quantitative measures used were size of the overlap (O), Spearman's footrule (F), and M-measure (M). The calculations according to these measures for the four rankings were made for TOP-10, TOP-100, TOP-200, and TOP-500 universities.

With a growing number of the university-participants, the values of those three measures were increasing overall, which means that the degree of similarity between the university rankings increased. The best similarity degree was observed between ARWU and HEEACT, and the worst – between THE-QS and WR, which is due to the best similarity between the methodologies of ranking universities in the former case, and the largest difference in the latter. The same results were obtained to prove the former case in (Huang, 2011; Chen & Liao, 2012). Besides, the calculations were made for those three measures and pair wise years within 2005–2008, which showed the stability of the rankings over time, though the values of F and M for ARWU were higher (Aguillo et al., 2010).

It is worth mentioning that the M-measure was introduced for adjusting the list length of universities for different rankings, i.e. for calculating the ranking similarity of non-overlapping universities. If there are two rankings with a different number of universities (m, n, $m > n$), in order to adjust their lists, the ranking with a shorter list sees the introduction of a larger number of universities, the number being M-N, under the same ranks equal $n + 1$. This procedure was first suggested in (Fagin et al., 2003) and then improved in (Bar-Ilan et al., 2006, 2007), being called the M-measure, which means the normalized similarity measure. In all the calculations made (Aguillo et al., 2010), the values of F and M turned out to be close. Logically, in all those calculations, M values were a bit smaller than F values.

The size of the overlap means the intersection of set of university names included in two rankings, Normalized Spearman's footrule is equal to one minus the sum of the absolute values of ranks differences of two rankings of the same-size items, divided by the maximum possible value of this sum. In our case, the latter indicator shows a degree of similarity between the two different university rankings with the same

number of university-participants. For two rankings of different sizes, a degree of this similarity (M-measure) is calculated in a more complex way, taking into account the adjustment of their sizes, as mentioned above, according to (Fagin et al., 2003).

The main idea of Aguillo et al. (2010) was further used by Shehatta and Mahmood (2016), who substituted the M-measure with Pearson's score correlation coefficient for similarity measure of the Overall Score of the two rankings. The calculations were made for ARWU, US News Ranking (abbreviated in the paper as USNWR), THE, OS, NTU, and URAP as of 2015 for TOP-50, TOP-100 and TOP-200 universities. On the whole, like in (Aguillo et al., 2010), the values of O (percentage of overlapping) and F (Spearman's rank correlation coefficient) increased along with an increase in the lists length of the TOP universities. At he same time, the values of Spearman's and Pearson's correlation coefficients were quite close.

The calculations of the longitudinal intra-system correlation for ARWU over the five-year period (2011–2015) are in good agreement with those observed by Aguillo et al. (2010) that used similarity measures for ARWU over the four-year period (2005–2008).

Most recently, the methodology described in (Aguillo et al., 2010) was used by Selten et al. (2020) for a comparative analysis of ARWU, THE, and QS over a seven-year period (2012–2018). In that paper, all the three measures – O, F, and M – were computed for each year for TOP-50, TOP-50-100, and TOP-100 in pair wise comparison of the three rankings. In general, the TOP-50 and TOP-100 between all the rankings are quite similar. In the TOP-50-100, similarity was poor, with low values of O, F, and M.

Longitudinal analysis of the seven-year period, including all pair wise combinations of different years, show that all the three rankings are stable over time, e.g. for ARWU, the O-measure changed from 85 per cent to 98 per cent; F – from 0.89 to 1.0; M – from 0.89 to 0.99.

So, on the whole, the analyses in (Aguillo et al., 2010; Shetatta & Mahmood, 2016; Selten et al., 2020) produce the similar results. But in the most recent paper, a quite interesting effect was detected. Though similarity for various rankings within the TOP-50 and TOP-100 range was quite good, it significantly deteriorated when comparing the last 50 universities from the TOP-100 of those rankings.

The confirmation of this effect can be found in (Khoszowjerdi & Kashani, 2013), who studied the similarities and statuses of the top Asian universities in the list of the TOP-200 universities in ARWU, QS, THE, HEEACT, Webometrics, and CWTS Leiden (for the year of 2010). They found out that Spearman's correlation coefficients were 0.78, 0.53, 0.58 for QS-Webometrics, QS-THE, and ARWU-HEEACT ranking pairs, respectively. In the latter case, a low Spearman's correlation coefficient between ARWU and HEEACT rankings can be accounted for by Asian universities being in the lowest parts of these rankings, which is in agreement with the calculations made in (Selten et al., 2020).

In addition to (Shehatta & Mahmood, 2016), we have analyzed the study described in (Olcay & Bulu, 2017), where pair wise Pearson's correlation was made for the

TOP-10, TOP-50, and TOP-100 of THE, QS, ARWU, Leiden, and URAP rankings (for the year of 2015). But this correlation was made not basing on the overlapping universities, as in the papers analyzed earlier, but by comparing ranks of a specific ranking with those of other rankings with similar list lengths of universities. The differences in such a correlation are of interest and can be seen by looking at the TOP-50s of the two comparable rankings in those two papers, which show that the two crosscorrelation matrices are quite different from each other, which was to be expected. However Olcay and Bulu (2017) did not specify which rank the interval estimation was based on in ARWU (101–150, 151–200, 301–400), or when there were sometimes no ranks for QS, ARWU and URAP (NA) rankings. It can be supposed, of course, that for interval estimations a class mark was used.

But it was clear that if in (Olcay & Bulu, 2017), instead of TOP-50 universities in THE, a TOP-50 universities in any other ranking had been used, quite a different correlation matrix would have been obtained, e.g. for the TOP-50 universities in THE, there are 35 corresponding ranks in the TOP-50 universities in ARWU.

In 2017, for the first time, U-Multirank ranking was used in comparative analysis of World University Rankings (Moed, 2017). It was created by the European Consortium, supported by the European Commission, in response to sharp criticism of the existing global university rankings. U-multirank compares institutions with similar institutional profiles and allows users to develop their own personalized rankings by selected indicators in terms of their own preferences. This ranking is multidimensional by nature and makes it possible to build 28 subject rankings. But it gives no opportunity to carry out a crosscorrelation analysis with other World University Rankings, as it does not rank universities in an ordinary way.

Moed (2017) used the data of the 2016 U-Multirank ranking for a comparative analysis with ARWU (2015), CWTS Leiden (2016), THE (2015–2016), and QS (2015–2016), as U-Multirank singles out TOP-100 universities and makes it possible to obtain quantitative data by its certain indicators. He obtained the university overlappings between 5 ranking systems, showing that for TOP-100s of those rankings, the total number of different universities was 194, and the number of the overlapping universities was 35. All the pair overlappings for the TOP-100s were found, as well as the first five performance groups of the countries according to the number of universities from each country in the five rankings. Of interest are the leading countries for each ranking: ARWU – USA (506/146); CWTS Leiden – USA (840/173); THE – UK (800/78); QS – UK (917/75); U-multirank – Germany (1293/84), where the former figure means the total number of the universities in the ranking, and the later – the number of the universities from a particular country in the ranking.

Pavel (2015) obtained the university distribution in the TOP-20, 100, 200, 300, 400, and 500 in ARWU for the 10 leading countries, using the data of 2014. According to this distribution, in the ARWU TOP-500, the number of the universities from the USA (148) significantly exceeded the numbers of German (39) and British (38) universities.

It is well known that ARWU, CWTS Leiden and HEEACT overestimate USA universities, whereas THE and QS underestimate USA universities and overestimate UK universities, which is confirmed in (Vidal & Filliatrean, 2014; Moed, 2017, etc.).

Moed (2017) calculated skewness of 17 selected indicators of ARWU, CWTS Leiden, THE, and QS rankings, which one can hardly see in other papers. He obtained Spearman's rank correlations between the selected indicators, and constructed a coloured diagram to show the correlation between QS and CWTS Leiden citation impact indicators for universities in six selected countries. This diagram shows that the country university points are considerably mixed-up, without forming any compact country cluster of points.

The intercorrelation between the 16 indicators of ARWU, THE, and QS rankings (for the year of 2016) was studied in (Mussard & James, 2018), in which the values of the indicators were converted into the unit interval according to the well-known max-min formulae. In the cross-correlation matrix, the correlation coefficients were classified by 5 levels, from very low to very high correlations, as well as in (Aquillo et al., 2010). In (Mussard & James, 2018), an attempt was made to qualitatively assess the level of the corruptible component for each studied indicator, which cannot be found in other sources.

There are a number of papers with calculations of the Pearson's score correlation between the Overall Score (Total Score) and indicator score (Hou et al., 2011, 2012; Chen & Liao, 2012; Soh, 2012, etc.).

In (Hou et al., 2012; Soh, 2012), there is a layer-by-layer Pearson's correlation between the Overall Score (Total Score) of the leading rankings and their indicators. For instance, for QS 2009 (Hou et al., 2012), the following rank change intervals were selected: 1–30; 30–70; 71–100; 90–110; 1–100, and for QS 2011–2012 (Soh 2012) – 1–100; 101–200; 201–300; 301–400.

The calculating results in these two papers show that the correlation coefficients in the TOP-100 of QS ranking are very close, and for the first four indicators (Academic peer review, Employer review, Faculty/Student ratio, Citation per faculty) they are quite high, whereas the layer-by-layer Pearson's correlation turned out to be low, with few exceptions. At the same time, university administrations should pay attention to the highest values of these coefficients for those intervals where a certain university belongs. If your university is in the TOP-100-110 of the QS ranking, in order to get into the lower end of the QS TOP-100, the indicators to improve are Employer review and Faculty/Student ratio, according to the calculated data in (Hou et al., 2012).

In (Hou et al., 2012), it was also shown that huge investment that universities make to hire foreign professors hardly influences their advances in rankings. The calculation in that paper truly show that the layer-by-layer Pearson's correlation between the Overall Score and Intrnational faculty indicator hardly exceeds a per cent.

Our literature review shows that eight World University Rankings were first analyzed in (Moskovkin et al., 2013): Webometrics, THE, QS, ARWU, HEACT, CWTS Leiden, URAP, and SIR – for the universities of the Mediterranean and Black Sea region countries (29 countries in total). One of the tasks of that article was the following: how a country from TOP-20 of Webometrics is represented in TOP-500 of all the eight World University Rankings studied in that paper. The article showed that 17 out of 29 countries had no universities in TOP-500 of at least one ranking. The

analytical procedures developed in that article make it possible quantitatively assess the competitiveness of higher education systems in various countries (Moskovkin et al., 2013).

The study in (Nethal & Harrison, 2014) included 9 rankings, adding CWUR (Saudi Arabia) to the 8 rankings previously studied in (Moskovkin et al., 2013).

Studying the whole range of the university rankings simultaneously suggests the idea of constructing an aggregated ranking, which will average their various methodologies. This task in several approximations was solved in (Nethal & Harrison, 2014; Moskovkin et al., 2015). The former applied a complex approach using partial least squares path modeling, which was tested for the intersection of the sets of university names from TOP-100s of ARWU, THE, and QS (2015). In the latter, a more simplified approach was applied (Moskovkin et al., 2015), when the calculations were made for THE, QS, Leiden, ARWU, Webometrics, and URAP rankings for the period of 2012–2013. As the URAP ranking was made for the TOP-2000, all the universities were ranked according to TOP-2000 Webometrics, as it ranks about 25000 universities and research institutions around the world. Bringing all the list lengths of universities to the same size was carried out according to (Bar-Ilan et al., 2016). The Aggregated Global University Ranking, AGUR, was calculated by summing up all the ranks in all the rankings. The calculations were made by means of a specially designed Python Programme. A very difficult task turned out to be recognizing different variations of university names used in different rankings, e.g. University of Harvard, Harvard University, Harvard Univ. This task was also recently viewed as a complicated one in (Selten et al., 2020).

The analysis of cross-correlation matrix showed that the best Spearman's correlation coefficients were between AGUR and URAP, which was quite expectable as the original list lengths of Webometrics and URAP were the same, whereas the list lengths of the other rankings were 3–5 times shorter (Moskovkin et al., 2015).

The literature review undertaken makes it possible to set several new Researh Qustions to broaden our understanding of the longitudinal analysis and the stability or instability effects of university rankings resulting from it, as well as to aggregate the universities and their Overall Scores (Total Scores) by countries:

Research Questions

RQ 1. Is there stability over a sufficiently long time interval (e.g. 5 years) in the TOP-100 of ARWU, THE and QS rankings?

RQ 2. What are the distribution and dynamics patterns of the number of universities and their average Overall (Total) Score by country over a sufficiently long time interval (5 years) for TOP-100 of ARWU, QS and THE rankings?

RQ 3. Are there any correlations between Country-Aggregated and 5-year averaged Indicators of Number of Universities and Overall (Total) Score for TOP-100 of ARWU, QS and THE rankungs?

RQ 4. Is there any temporary stability in layer-by-layer Pearson's correlation between Indicators and Overall (Total) Score for ARWU, QS and THE rankings,

and how can these correlations be used to improve the positioning of universities in World University Rankings?
RQ5. Is the proof of "Sin no. 7: inconsistency between changes in ranking and overall score" (Soh 2017) wrong?

This research will use a five-year interval (2014–2018) for TOP-100s of ARWU, QS, and THE rankings.

3. Materials and methods

Among a wide range of world university rankings, for further comparative analysis, we chose only three: ARWU, QS and THE, which are the oldest rankings with an established methodology. In addition, they are popular with all university administrators throughout the world, who on a regular basis monitor the performance of their universities in these rankings, with researchers who usually use these ratings for comparative analysis, and with students who mainly use these three rankings to select universities to apply for. The prestige of these rankings is also confirmed by the fact that many governments in the world include only these three nakings in their strategic academic excellence programs to improve university competitiveness and university benchmarking procedures to track the universities from their countries entering the upper lines of these rankings (for example, Russia, Arab countries, etc.).

Below is a brief outlook of the methodology of these rankings.

ARWU ranking sets the highest criteria for academic excellence and includes 6 indicators: 1. Alumni of an institution winning Nobel Prizes and Fields Medals (Alumni, 10%); 2. Staff of an institution winning Nobel Prizes and Fields Medals (Staff, 20%); 3. Highly cited researchers (HiCi, 20%); 4. Papers published in Nature and Science (N&S, 20%); 5. Papers indexed in Science Citation Index-Expanded and Social Citation Index (PUB, 25%): 6. Per capita academic performance of an institution (PCP, 10%).

The QS methodology also includes 6 indicators: 1. Academic reputation (40%); 2. Employer reputation (10%); 3. Faculty/Student ratio (20%); 4. Citation per faculty ((20%); 5. International faculty ratio (5%); 6. International student ratio (5%).

THE ranking includes 5 consolidated indicators: 1. Industry income – innovation (2.5%); 2. International diversity (similar to indicators 5 and 6 of the QS methodology, 5%); 3. Teaching (includes 5 indicators, among which Reputational survey for teaching, 30%); 4. Research (includes 4 indicators, among which Reputational survey for research, 30%); 5. Citations (32.5%).

As can be seen, the British rankings show more similarity between themselves, since they used to be one ranking which later split into two independent rankings. In addition to the similar indicators for academic and employer surveys and international diversity, the publication activity and citations ratios in these rankings are calculated using the Scopus database, unlike the ARWU ranking. This well explains the greater

similarity of these rankings when they are compared with each other, rather than with other rankings, which can be seen well in all the studies on a pairwise correlation we used for our review, as well as in our country-aggregated calculations in Table 9.

TOP-100s of the universities with their Total Score (Overall Score) values for 2014–2018 were obtained from the official sites of ARWU, QS, and THE university rankings (primary data). They were used to study the dynamics of the positioning of universities over a five-year period (Appendix 1, Tables A1–A3). Appendix 1 was further used to calculate the average ranks and the range of their fluctuations over the five years (Appendix 2, Tables A4–A6).

The choice of a five-year interval for the comparative analysis of the three selected rankings was made as this interval was sufficient to study their mobility and structural stability; moreover, over a wider time interval, we could have encountered dramatic changes in the methodology for calculating the QS and THE rankings, as well as their sample size.

Based on primary data, all the universities for the three rankings under study were aggregated by country, and for each ranking, the total number of universities and their average Overall Scores (Total Scores) for each country were calculated by year. This was done for the entire five-year period, and besides a cross-correlation matrix was calculated for six average indicators of the number of universities aggregated by country and averaged over a five-year period of time (N^{ave}_{ARWU}, N^{ave}_{QS}, N^{ave}_{THE}), Total Score (Overall Score) (TS^{ave}_{ARWU}, TS^{ave}_{QS}, OS^{ave}_{THE}).

For the TOP-200 of THE ranking, the layer-by-layer Pearson's correlations between the Total Score and all the indicators of this ranking are made in order to show a heterogeneous structure of this ranking.

4. Results and discussion

Tables A4–A6 of Appendix 2 clearly show that the greater the range of fluctuations in the positions of universities in the ARWU, QS, and THE rankings over a five-year period, the less the correspondence of their ranks in 2014 compared to the average rank. In these Tables, the universities are ranked by 2014. From these Tables, it can be seen that, in general, the range of fluctuations in the university positions in the rankings is greater in the lower parts of the rankings, when compared with the upper and middle parts of these rankings.

For interval estimates of the university ranks, when calculating the fluctuation range (the difference between the highest and lowest ranks in the Tables in Appendix 1), the middle of the interval was used.

For a fluctuation range of university ranks in the rankings under study, a five-level scale in increments of 5 and with a right open interval was introduced. Distribution of all the universities from Appendix 2 according to this scale is shown in Table 1. A simple example can be used to show how this Table was built: within the range of ranks 16–20 for the ARWU ranking based on this Appendix, in the "Fluctuation

Table 1
Distribution of number of universities on a five-level scale of fluctuation range

Fluctuation range of university ranks	ARWU	QS	THE
0–5	32	19	26
6–10	23	21	13
11–15	12	22	11
16–20	4	6	14
> 20	29	32	36
Total	100	100	100

range" line, we can see four universities: Utrecht University; Purdue University-West Lafayette; University of Bristol and University of Helsinki, which fell into this interval.

From Table 1, we can see that, in general, the ARWU ranking was more stable over the period under review than the QS ranking, and, in turn, QS was more stable than the THE ranking, which is due to ARWU having a more predictable ranking methodology based on hard data, compared to the UK rankings methodologies. Obviously, the same result can be obtained when calculating the mean ranges for the entire sample of the universities.

Using Tables A4–A6 in Appendix 2, the first groups of twenty most stable and most unstable universities were made according to the dynamics of their positions in the rankings under consideration over a five-year period of time (Tables 2–4). In these Tables, the most stable universities were identified, which entered TOP-20s of all the three rankings: Harvard University, Stanford University, Princeton University, University Chicago, ETH Zurich, Massachusetts Institute of Technology, University of Cambridge, California University of Technology, Yale University, Cornell University, and University of Oxford. Thus, 11 universities are in TOP-20 of the most stable universities in all the rankings, out of which 8 universities are from the US.

An analysis of the data in Tables 2–4 makes it possible to arrive at some general conclusions. All the most stable universities, except for one in Table 2, are ranked in the TOP-50s of the three rankings under study, and all the most unstable universities are ranked in the second half of the ranking tables (TOP-51-100). Among the most unstable universities in all three rankings, there are practically no overlapping universities, which means that the similarity in the lower parts of the ranking tables under study is very weak.

These conclusions were also more rigorously confirmed on the basis of calculating Spearman's rank correlation between different temporary states of the three considered rankings in the TOP-50 and TOP-51-100 layers. For example, this coefficient in the TOP-50 of the ARWU ranking between its most remote time points (the years of 2014 and 2018) was equal to 0.911510, whereas the similar correlation coefficient for TOP-51-100 of the ARWU ranking was equal to 0.551593. For the QS ranking, the corresponding correlation coefficients were 0.800294 and 0.614809, for THE ranking – 0.837959 and 0.261670, respectively.

Table 2
First twenty-performance groups of most stable and most unstable universities in dynamics of their positions in ARWU ranking over five years (2014–2018)

Most stable universities			Most unstable universities		
Rank in 2014	University	Fluctuation range	Rank in 2014	University	Fluctuation range
1	Harvard University	0	92	University of Rochester	83
2	Stanford University	0	98	Texas A & M University	77
6	Princeton University	0	52	Rutgers, The State University of New Jersey – New Brunswick	73
8	Columbia University	1	71	The Hebrew University of Jerusalem	58
9	University of Chicago	1	75	Brown University	50
12	University of California, Los Angeles	1	97	Swiss Federal Institute of Technology Lausanne	49
14	University of California, San Diego	1	78	Osaka University	47
19	Swiss Federal Institute of Technology Zurich	1	99	Georgia Institute of Technology	45
3	Massachusetts Institute of Technology	2	55	University of California, Davis	43
4	University of California-Berkeley	2	93	University of California, Santa Cruz	40
5	University of Cambridge	2	86	University of Arizona	39
7	California Institute of Technology	2	87	University of Utah	38
11	Yale University	2	88	Arizona State University	37
13	Cornell University	2	91	University of Basel	37
15	University of Washington	2	48	University of California, Irvine	36
16	University of Pennsylvania	2	95	University of Strasbourg	36
17	The Johns Hopkins University	2	94	University of Bonn	31
10	University of Oxford	3	62	Carnegie Mellon University	30
18	University of California, San Francisco	3	64	The Ohio State University – Columbus	30
61	Uppsala University	3	85	The University of Queensland	30

The pimary data were used to calculated the number of the universities from different countries over a five-year period, as well as the average Overall Score (Total Score) by country and year (Tables 5–7). The number of the universities and the Overall Scores (Total Scores) averaged over all the years are shown in the last two columns of these Tables. The United States is far ahead of the other countries in terms of the number of its universities represented in all the rankings, sharing the first two places in the Overall Score (Total Score) with the United Kingdom. It is worth noting that the 5-year averages of the Overall Score (Total Score) for the US and UK in the ARWU rankings are half as much as in the other two rankings. This is due to the different numbers of the universities from the two countries present in

Table 3
First twenty-performance groups of most stable and most unstable universities in dynamics of their positions in QS ranking over five years (2014–2018)

Most stable universities			Most unstable universities		
Rank in 2014	University	Fluctuation range	Rank in 2014	University	Fluctuation range
1	Massachusetts Institute of Technology (MIT)	0	91	Erasmus University Rotterdam	88
5	University of Oxford	1	83	Université de Montréal	66
4	Harvard University	2	75	Leiden University	47
11	University of Chicago	2	96	Aarhus University	45
27	University of California, Berkeley (UCB)	2	80	Utrecht University	44
36	Kyoto University	3	67	University of Helsinki	43
2	University of Cambridge	4	72	London School of Economics and Political Science (LSE)	37
6	UCL (University College London)	4	81	Uppsala University	36
8	California Institute of Technology (Caltech)	4	45	University of Copenhagen	35
9	Princeton University	4	86	Delft University of Technology	34
32	Seoul National University	4	95	University of California, Davis	33
48	The University of New South Wales	4	60	Lund University	32
73	Tohoku University	4	93	Durham University	32
7	Stanford University	5	71	Fudan University	31
12	ETH Zurich (Swiss Federal Institute of Technology)	5	35	Ecole Polytechnique	30
19	Cornell University	5	47	Tsinghua University	30
28	University of Hong Kong	5	74	Trinity College Dublin	30
30	The University of Manchester	5	90	University of Groningen	30
3	Imperial College London	6	88	University of St Andrews	29
10	Yale University	6*	98	Queen Mary, University of London (QMUL)	29

Note. *The University of Pennsylvania, University of Edinburgh, Australian National University had a similar fluctuation range.

these rankings and their specific calculation methodologies (as mentioned earlier, the British rankings have conventionally similar methodologies, which are fundamentally different from the methodology applied by the ARWU ranking).

Table 5 shows that 7 universities from the USA fell out of the ARWU TOP-100, whereas universities from other countries burst into it instead: 3 universities from China, 2 universities from Singapore, as well as universities from the UK and Australia (one university from each). In the QS TOP-100, the USA increased its presence by 3 universities, and China – by 4. The Netherlands lost 3 universities in the ranking and Canada – 2 (Table 6). In the THE TOP-100, the major negative trend was shown

Table 4
First twenty-performance groups of most stable and most unstable universities in dynamics of their positions in THE ranking over five years (2014–2018)

Most stable universities			Most unstable universities		
Rank in 2014	University	Fluctuation range	Rank in 2014	University	Fluctuation range
7	Princeton University	0	85	Middle East Technical University	615
4	Stanford University	1	91	University of Massachusetts	134
9	Imperial College London	1	63	Scuola Normale Superiore di Pisa	121
19	Cornell University	1	52	Korea Advanced Institute of Science and Technology (KAIST)	96
3	University of Oxford	2	87	University of Notre Dame	86
6	Massachusetts Institute of Technology	2	88	Tufts University	81
11	University of Chicago	2	90	Ghent University	79
14	Columbia University	2	86	University of Arizona	77
24	Carnegie Mellon University	2	66	Pohang University of Science and Technology	76
33	University of Melbourne	2	99	Technical University of Munich	58
5	University of Cambridge	3	67	University of Göttingen	56
18	Duke University	3	98	Stockholm University	55
72	Erasmus University Rotterdam	3	62	École Polytechnique	54
1	California Institute of Technology	4	83	Durham University	44
2	Harvard University	4	94	McMaster University	36
10	Yale University	4	50	Seoul National University	35
13	ETH Zurich	4	96	Vanderbilt University	34
17	University of Michigan	4	59	Kyoto University	33
20	University of Toronto	4	70	Heidelberg University	33
25	National University of Singapore	4*	69	Rice University	32**

Note. *University of Manchester and Brown University had a similar fluctuation range. Note. **Free University of Berlin had a similar fluctuation range.

by the USA (4 US universities fell out of the ranking), while China and Germany increased the number of their universities in the ranking table by 2 each (Table 7).

Over the 5 years, the universities from 18 countries were represented in the TOP-100 rankings by ARWU and THE, and the universities from 21 countries – in the QS TOP-100. The countries in Tables 5–7 are ranked by the number of universities as of 2018.

The aggregated indicators for the five-year period presented in the last two columns of Tables 5–7 can be seen in Table 8. In this Table, there are 25 countries, the names of which make up a union of sets of names of the countries shown in Tables 5–7. At the same time, at the intersection of sets of these countries' names are the following 15 countries: US, UK, Australia, Switzerland, France, Canada, Netherlands, Japan, China, Sweden, Denmark, Singapore, Finland, and Belgium.

Table 5
Distribution of number of universities and average total score by country in TOP-100 of ARWU ranking, 2014–2018

Country	2014		2015		2016		2017		2018		2014–2018	
	N_{ARWU}	TS^{ave}_{ARWU}	N_{ARWU}	TS^{ave}_{ARWU}	N_{ARWU}	TS^{ave}_{ARWU}	N_{ARWU}	TS^{ave}_{ARWU}	N_{ARWU}	TS^{ave}_{ARWU}	N^{are}_{ARWU}	TS^{ave}_{ARWU}
USA	53	40.52	51	40	51	39.62	48	41.06	46	41.29	49.6	40.43
UK	7	40.09	9	39.99	8	43.34	9	42.36	8	43.91	8.4	42.37
Germany	5	29.1	5	29.02	4	31.28	5	30.76	5	30.96	4.8	30.22
Australia	5	27.65	4	27.65	5	28.88	6	29.3	6	29.43	5	28.78
Switzerland	5	30.34	4	32.03	4	32.68	5	32.16	5	32	4.6	31.84
France	4	30.6	4	30.28	3	31.07	3	33.03	4	33.2	3.6	31.64
Canada	4	32.5	4	31.9	4	32.88	4	34.3	4	32.65	4	32.85
Netherlands	3	27.05	4	26.88	3	27.27	4	28.83	3	28.07	3.6	27.62
Japan	3	36.63	4	33.33	4	33.1	3	35.13	3	35.03	3.4	34.64
China	0	0	0	0	2	28.65	2	30.65	3	31.13	1.4	18.09
Sweden	3	29.4	3	29.27	3	29.57	3	30.43	3	30.6	3	29.85
Denmark	2	30.95	2	31.5	2	33.2	2	33.8	2	33.95	2	32.68
Israel	2	27.4	2	27.45	2	27.1	1	26.6	2	26.9	1.8	27.09
Singapore	0	0	0	0	1	26.5	1	26.8	2	26.5	0.8	15.96
Russia	1	26.1	1	25.3	1	26.2	1	26.6	1	27	1	26.24
Finland	1	27.5	1	28.2	1	29.9	1	31.5	1	31	1	29.62
Norway	1	28.1	1	29.4	1	28.6	1	29.9	1	29.8	1	29.16
Belgium	1	24.2	1	24.7	1	25.6	1	26.9	1	27	1	25.68
Total	**100**		**100**		**100**		**100**		**100**		**100**	

Table 6
Distribution of number of universities and average total score by country in TOP-100 of QS ranking, 2014–2018

Country	2014		2015		2016		2017		2018		2014–2018	
	N_{QS}	TS^{ave}_{QS}	N_{QS}	TS^{ave}_{QS}	N_{QS}	TS^{ave}_{QS}	N_{QS}	TS^{ave}_{QS}	N_{QS}	TS^{ave}_{QS}	N^{ave}_{QS}	TS^{ave}_{QS}
USA	28	86.47	30	84.7	32	80.77	31	81.44	31	79.25	30.4	82.53
UK	19	83.04	18	83.86	18	79.18	16	79.86	18	76.02	17.8	80.39
China	7	75.28	9	82.24	9	78.87	12	75.94	11	74.99	9.6	78.54
Australia	8	80.33	7	80.71	6	78.62	7	77.33	7	75.44	7	78.49
Japan	5	80.52	5	80.52	5	75.92	5	76.44	5	73.9	5	77.46
South Korea	3	79.83	3	79.97	4	72.45	4	74.2	4	71.25	3.6	75.54
France	2	87.6	2	86.5	2	79.3	2	76.95	3	69.27	2.2	79.92
Germany	3	80.2	4	74.725	3	70.77	3	71.07	3	69.13	3.2	73.18
Switzerland	4	85	4	83.18	4	79.18	4	79.6	3	81.57	3.8	81.71
Canada	5	82.64	4	81.75	4	77.48	4	77.83	3	80.17	4	79.97
Netherlands	6	74.55	5	73.3	2	73.2	2	75.2	3	68.07	3.6	72.86
Singapore	2	87.55	2	94.05	2	91.45	2	91.35	2	91.65	2	91.21
Belgium	1	74.1	1	72.4	1	67.9	1	69.4	1	63.4	1	69.44
New Zealand	1	72	1	72.4	1	67.3	1	67	1	62.8	1	68.3
Sweden	2	76.25	2	73.15	3	65	2	66.6	1	62.1	2	68.62
Malaysia	0	0	0	0	0	0	0	0	1	62.6	0.2	12.52
Argentina	0	0	0	0	1	65.8	1	69.1	1	66.2	0.6	40.22
Denmark	2	74.76	1	75.7	1	70.2	1	69.2	1	63.5	1.2	71.08
Russia	0	0	0	0	0	0	1	65	1	62.3	0.4	25.46
Ireland	1	75.3	1	74.3	1	62.8	1	65.7	0	0	0.8	55.62
Finland	1	76.4	1	70.1	1	64.7	0	0	0	0	0.6	42.24
Total	**100**		**100**		**100**		**100**		**100**		**100**	

Of the 25 countries in Table 8, the top 11 countries make up a representative sample for which the number of universities is more than or equal to 2. For this sample, TS^{ave}_{QS} is approximately equal to OS^{ave}_{THE}, whereas TS^{ave}_{ARWU} is approximately 2-2.5 times more than TS^{ave}_{QS} and OS^{ave}_{THE}.

The data from Table 8 were used for calculating a cross-correlation matrix by means of Excel (Table 9). In it, the worst values of the Pearson's correlation coefficient of under 0.5 were observed for the pairs (TS^{ave}_{ARWU}, N^{ave}_{QS}) and (TS^{ave}_{QS}, TS^{ave}_{ARWU}). This is due to the fact that the methodologies of the ARWU and QS rankings, as well as the lists of the universities they rank, are the most different in comparison with the other pairs in Table 9.

We developed the ideas described by Hou et al. (2012) and Soh (2012) on calculating the layer-by-layer Pearson's correlation between the Overall Score (Total Score) of the leading rankings and their indicators. By studying those papers, we can see that in the middle and lower table parts of World University Rankings, the Overall Scores (Total Scores) are dense, unlike those in upper table parts of these rankings. It is proved by the interval estimations of ranks, which are introduced for similar values of Overall Scores (Total Scores). This explains well the situation with low values of correlation coefficients in middle and lower table parts of rankings, which can be due to the fact that the Overall Scores (Total Scores) and rankings are very sensitive to weight variations, especially for middle- and low-ranked universities, which was well shown in (Pinar et al., 2019), as well as to variations in indicator values.

Table 7
Distribution of number of universities and average overall score by country in TOP-100 of THE ranking, 2014–2018

Country	2014		2015		2016		2017		2018		2014–2018	
	N_{THE}	OS^{ave}_{THE}	N_{THE}	OS^{ave}_{THE}	N_{THE}	OS^{ave}_{THE}	N_{THE}	OS^{ave}_{THE}	N_{THE}	OS^{ave}_{THE}	N^{ave}_{THE}	OS^{ave}_{THE}
USA	45	71.54	39	75.8	41	76.64	41	76.66	41	77.39	41.4	75.61
UK	11	72.52	16	72.45	12	76.54	12	76.34	11	78.81	12.4	75.33
Germany	6	60.43	9	65.93	9	66.83	10	66.09	8	68.29	8.4	65.51
Netherlands	6	59.13	8	65.23	8	64.33	7	66.1	7	66.69	7.2	64.3
Australia	5	63.7	6	67.3	6	68.17	6	68.27	6	68.58	5.8	67.2
China	4	65.63	4	70.05	5	72.22	5	74.9	6	74.22	4.8	71.4
Canada	4	69	4	72.65	3	77.33	4	73.9	5	72.22	4	73.02
Switzerland	3	71.3	2	82.2	3	75.47	3	74.63	3	76.4	2.8	76
Sweden	3	58.67	3	66.13	3	66.43	3	66.27	3	66.9	3	64.88
France	2	60.15	1	69	1	65.8	1	65.2	2	69.75	1.4	65.98
Japan	2	69.45	2	65.5	2	67.65	2	68.55	2	70.7	2	68.37
South Korea	3	63.47	1	60.5	2	62.75	2	62.9	2	65.6	2	63.04
Singapore	2	67.75	2	73.7	2	75.85	2	76.65	2	77.3	2	74.25
Belgium	2	59.95	1	74.8	1	73.8	1	71.8	1	72.6	1.2	70.59
Finland	0	0	1	61.9	1	61.2	1	61.7	1	62.4	0.8	49.44
Italia	1	61.9	0	0	0	0	0	0	0	0	0.2	12.38
Denmark	0	0	1	61	1	60.3	0	0	0	0	0.4	24.26
Turkey	1	56.6	0	0	0	0	0	0	0	0	0.2	11.32
Total	**100**		**100**		**100**		**100**		**100**		**100**	

Table 8
Distribution of average ranks and average total score by countries in TOP-100 of ARWU, QS, and THE rankings over five years (2014–2018)

#	Country	N^{ave}_{ARWU}	N^{ave}_{QS}	N^{ave}_{THE}	TS^{ave}_{ARWU}	TS^{ave}_{QS}	OS^{ave}_{THE}
1	USA	49.6	30.4	41.4	40.43	82.53	75.61
2	UK	8.4	17.8	12.4	42.37	80.39	75.33
3	Germany	4.8	3.2	8.4	30.22	73.18	65.51
4	Australia	5	7	5.8	28.78	78.49	67.2
5	Switzerland	4.6	3.8	2.8	31.84	81.71	76
6	France	3.6	2.2	1.4	31.64	79.92	65.98
7	Canada	4	4	4	32.85	79.97	73.02
8	Netherlands	3.6	3.6	7.2	27.62	72.86	64.3
9	Japan	3.4	5	2	34.64	77.46	68.37
10	China	1.4	9.6	4.8	18.09	78.54	71.4
11	Sweden	3	2	3	29.85	68.62	64.88
12	Denmark	2	1.2	0.4	32.68	71.08	24.26
13	Israel	1.8	0	0	27.09	0	0
14	Singapore	0.8	2	2	15.96	91.21	74.25
15	Russia	1	0.4	0	26.24	25.46	0
16	Finland	1	0.6	0.8	0	42.24	49.44
17	Norway	1	0	0	29.16	0	0
18	Belgium	1	1	1.2	25.68	69.44	70.59
19	South Korea	0	3.6	2	0	75.54	63.04
20	New Zealand	0	1	0	0	68.3	0
21	Malaysia	0	0.2	0	0	12.52	0
22	Argentina	0	0.6	0	0	40.22	0
23	Ireland	0	0.8	0	0	55.62	0
24	Italia	0	0	0.2	0	0	12.38
25	Turkey	0	0	0.2	0	0	11.32

Table 9
Cross-correlation matrix for country-aggregated and 5-year-averaged indicators of number of universities and Overall Score (Total Score) for TOP-100s of ARWU, QS, and THE rankings

	N^{ave}_{ARWU}	N^{ave}_{QS}	N^{ave}_{THE}	TS^{ave}_{ARWU}	TS^{ave}_{QS}	OS^{ave}_{THE}
N^{ave}_{ARWU}	1					
N^{ave}_{QS}	0.749759	1				
N^{ave}_{THE}	0.845343	0.843724	1			
TS^{ave}_{ARWU}	0.778316	0.428448	0.508951	1		
TS^{ave}_{QS}	0.518666	0.525367	0.533442	0.385187	1	
OS^{ave}_{THE}	0.642989	0.585266	0.657174	0.564848	0.79959	1

The graphical presentation of such calculations, showing the routes of transition of indicator values and integral indicators from one university to another, made it possible to study the distribution densities of these values in different ranges of the rankings. But most importantly, such calculations help determine within these ranges the most important indicators with the highest values of the correlation coefficients, using which university administrations can solve the task of improving the performance of their universities in global university rankings.

Table 10
Correlation coefficients between indicators and Overall Score by THE ranking ranges, 2020

Rank range	Teaching score	Research score	Citations score	Industry income score	International outlook score
THE 1-30	0.826418	0.812862	0.42888	0.220187	0.311279458
THE 31-60	0.52864	0.729543	−0.11658	0.253549	0.075105007
THE 61-90	0.224387	0.489563	0.009208	−0.06913	−0.02971853
THE 91-120	0.189157	0.195004	−0.0193	0.170616	−0.051060205
THE 121-150	0.195912	0.454236	−0.11601	−0.25404	0.015239169
THE 151-180	0.319006	0.279049	−0.21152	0.141398	−0.008881019
THE 181-200	0.067282	0.208325	−0.07701	0.246971	−0.016779239
THE 1-100	0.901465	0.923397	0.466281	−0.02374	0.203370169
THE 1-200	0.886084	0.922161	0.417313	0.076996	0.167241474

We made such correlations for the ARWU TOP-100 with three ranges, for the THE TOP-200 with seven ranges and for the QS TOP-210 with seven ranges over three years (2018–2020). For ARWU, apart from the range 1–30, for which the correlations between partial indicators and the Total Score were approximately the same, the most sensitive indicators in relation to the Total Score in almost all three variants of the calculation for the range 31–60 turned out to be the following indicators: HiCi (in all three cases) and N&S (in the first two cases for 2018 and 2019), the Pearson's correlation coefficient of these two indicators varying from 0.36 to 0.4. All the other values of this coefficient for 6 indicators within the ranges 31–60 and 61–90 were under 0.27, and in some cases even negative.

Figure 1 shows the regression equation for the HiCi Score (R = 0.36525), where dots and lines show the positions of universities in the ARWU ranking (the values of the indicator and Total Score) and transitions to the nearest neighboring universities ranked one position above. The graph shows two areas of dense points in relation to the Overall Score.

These points make it possible to easily retrieve the names of all 30 universities. For example, the fifth point from the top corresponds to the University of Melbourne, which was ranked 35th in the ARWU ranking in 2020 with a Total Score of 36. If this university manages to increase the HiCi indicator from 40.8 to 44.3 over the next several years, then it can highly likely go up to the 31st place, where the University of North Carolina at Chapel Hill was located in 2020.

For the seven ranges of the THE ranking, the complete correlation table for 2020 can be seen in Table 10, which shows that within the ranges 1–3 and 5 there are 6 sufficiently high values of the correlation coefficient ($R > 0.43$).

Figure 2 shows the transition of the Research Score and Overall Score of the ranking under study from one university to another (sequentially from a university ranked 90 all the way to rank 61). The dense points can be seen in the lower part of the broken line. A similar situation is true for the QS ranking, for which no calculations will be provided in this paper. It is important to note that if the values of the integral indicators of universities are in the areas of their concentration, then small fluctuations

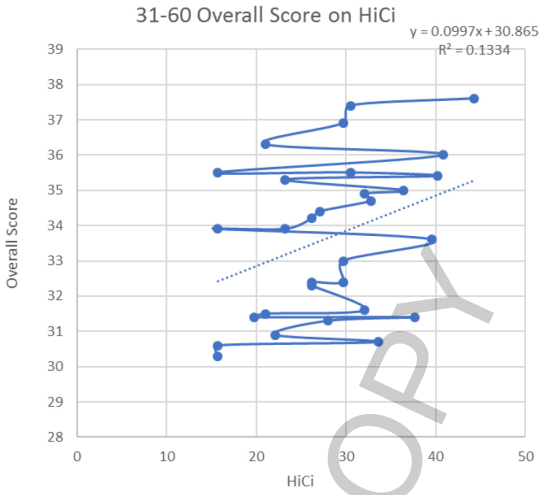

Fig. 1. Regression relationship between HiCi Score and Total Score for the range 31–60. ARWU 2020.

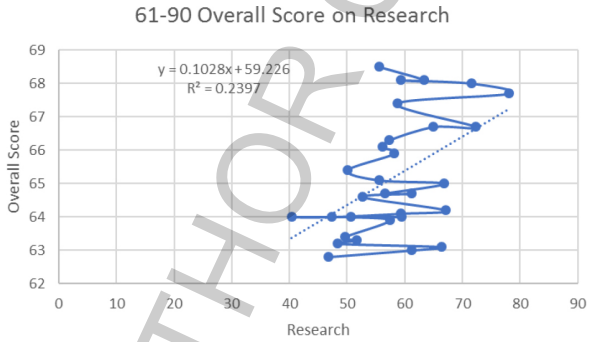

Fig. 2. Regression relationship between Research Score and Overall Score. THE 2020.

in the values of the ranking indicators will have a strong impact on the values of their integral indicators. Figures 1 and 2 make it possible to see a previously unknown effect: if the Overall Score (Total Score) is a monotonically increasing function of the university ranks, then the HiCI Score (Fig. 1), the Research Score (Fig. 2), and others are oscillating functions.

In conclusion, we would like to mention one paradox identified by Soh (2017), which he called “Sin no. 7: inconsistency between changes in ranking and overall score”, saying: “Many universities with better ranking between years are found to have lower Overall Scores, and the opposite is also true. Does it make sense when a university obtaining a lower Overall Score than in the previous year is placed in a higher position this year, and vice versa?" (Soh, 2017, 110). He further concludes that “ranking is not a trustworthy indication of changes in academic excellence as

indicated by the Overall" (ib., 110). Not that there is anything wrong with that as this is a usual situation for all rankings, and a number of university administrators see no sin in it. To illustrate it, let us look at Cornell University, as one of numerous examples, which in 2014 was ranked 13th in the TOP-100 ARWU Ranking, and trace the dynamics of its position in this ranking. For three years, it retained its ranking position, with a slight decline in its Overall Scores, but in 2017, its Overall Score went up by 0.6 points, though its rank went down to 14th. This can be accounted for by tough competition from other universities. In this case, the University of Washington ousted Cornell University from its 13th place. When one university takes measures to increase its Overall Score, but another university, which was originally ranked lower, takes more powerful measures to increase, say, its publication activity, it may as well outperform the former university by Overall Score. So there is actually no paradox in this due to strong competitive pressure from lower ranked universities.

5. Conclusion

The global reputation race among universities, launched in 2003, has led to the creation of 13 World University Rankings: in the UK – 2 rankings, in Spain – 2, in Russia – 2, and in China, Taiwan, the Neterlands, the EU, Turkey, the USA, and Saudi Arabia – 1 per each. After launching the first three rankings (ARWU, THE, and QS), a cluster of publications appeared on the qualitative comparative analysis of the methodologies applied by these rankings.

By the end of 2007, Webometrics, HEEACT, CWTS Leiden joined in. The first author to conduct a quantitative comparative analysis of these rankings, taking into account the combined THE and QS (THE-QS) and excluding the CWTS Leiden Ranking due to its regional (European) character, was Aguillo (2010). That paper was followed by a cluster of publications on the quantitative comparative analysis of university rankings. The analysis made in them revealed a number of disadvantages of these ratings, later summarized by Soh (2017).

A large number of such rankings with different methodologies necessitated the development of aggregated university rankings, some of which are discussed in our paper.

In our opinion, the most interesting features found in the comparative analyses of university rankings are as follows:

1. The similarity between the rankings deteriorates in their bottom parts;
2. Overal Scores (Total Scores) of the rankings are denser in their bottom parts, due to a higher sensitivity of rankings to variations in weight coefficients in their bottom parts;
3. Layer-by-layer correlation between Overal Scores (Total Scores) and indicators of World University Rankings deteriorates from top parts to bottom parts.

We view all these three conclusions as interconnected.

The literature review made it possible to set a number of new tasks to stabilize the university rankings, as well as to aggregate the number of universities and their Overall Scores (Total Scores) by country. Our study was conducted for a five-year time interval (2014–2018) for TOP-100s of ARWU, QS, and THE Rankings.

The study described in this paper helps us answer the research questions posed in the Introduction.

RQ1. The dynamic analysis of the positioning of the universities over a five-year period, with calculating their average ranks and the fluctuation range over that period, showed that the larger the fluctuation range, the less the correlation of university ranks in 2014 with the average rank, and also that the fluctuation range of university ranks was higher in the bottom parts of the rankings, when compared with that in the upper parts. When introducing a five-level flat scale for the above fluctuation range, it was shown that the ARWU ranking demonstrated more stability over the period under study than the QS ranking, whereas the latter, accordingly, was more stable than the THE ranking. The similar results were obtained when calculating Spearman's rank correlation between different temporary states of the three rankings under consideration in the TOP-50 and TOP-51-100 layers. From the above calculations, we can conclude that universities that enter the upper parts of the rankings will remain there indefinitely, which university administrators intuitively understand.

RQ2. The country distribution of the universities was carried out for the period under study, and the average values of the Overall Scores (Total Scores) were calculated by country and by year. The universities of the United States and Great Britain left other universites far behind by these indicators. An analysis for all three rankings has shown that the country distributions of the number of universities and their average Overall Score (Total Score) remain stable over time.

RQ3. Calculation of the cross-correlation matrix for six aggregated indicators of Overall Score (Total Score) and the number of universities in three rankings showed the worst correlation of these indicators between ARWU and QS rankings, which is due to the most different methodologies and lists of universities used in these rankings.

RQ4. A significant layer-by-layer heterogeneity of the rankings under study is shown, in which the correlation between the values of their indicators and integral indicators decreases from the upper layers to the lower ones. It is shown that the layer-by-layer selection of the most correlated pairs of the indicators and integral indicators makes it possible to solve managerial tasks for a more well-thought promotion of universities in global university rankings.

RQ5. In the longitudinal analysis of one of the rankings, we showed that the seventh sin of World University Rankings, discovered by Soh (2017) and associated with a drop in a university rank with a simultaneous increase in its Overall Score (Total Score), is not a sin as it is easily accounted for by competitive pressure from lower ranked universities.

The prospects of further development of these studies can be seen in involving all other university rankings in these calculations.

Conflict of interest

The authors have no conflict of interests to declare.

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Appendix 1

Table A1
Dynamics of ranks in ARWU TOP-100, 2014–2018

	ARWU	2014	2015	2016	2017	2018
1	Harvard University	1	1	1	1	1
2	Stanford University	2	2	2	2	2
3	Massachusetts Institute of Technology	3	3	5	4	4
4	University of California-Berkeley	4	4	3	5	5
5	University of Cambridge	5	5	4	3	3
6	Princeton University	6	6	6	6	6
7	California Institute of Technology	7	7	8	9	9
8	Columbia University	8	8	9	8	8
9	University of Chicago	9	9	10	10	10
10	University of Oxford	10	10	7	7	7
11	Yale University	11	11	11	11	13
12	University of California, Los Angeles	12	12	12	12	11
13	Cornell University	13	13	13	14	12
14	University of California, San Diego	14	14	14	15	15
15	University of Washington	15	15	15	13	14
16	University of Pennsylvania	16	17	18	17	16
17	The Johns Hopkins University	17	16	16	18	18
18	University of California, San Francisco	18	19	21	21	21
19	Swiss Federal Institute of Technology Zurich	19	20	19	19	19
20	University College London	20	18	17	16	17
21	The University of Tokyo	21	21	20	24	22
22	The Imperial College of Science, Technology and Medicine	22	23	22	27	24
23	University of Michigan-Ann Arbor	23	22	23	25	27
24	University of Toronto	24	25	27	23	23
25	University of Wisconsin-Madison	25	24	28	28	28
26	Kyoto University	26	26	32	35	35
27	New York University	27	27	29	29	32
28	Northwestern University	28	28	26	22	25
29	University of Illinois at Urbana-Champaign	29	29	31	37	41
30	University of Minnesota, Twin Cities	30	30	33	34	37
31	Duke University	31	31	25	26	26
32	Washington University in St. Louis	32	32	24	20	20
33	Rockefeller University	33	33	37	36	30
34	University of Colorado at Boulder	34	34	38	43	39
35	Pierre and Marie Curie University-Paris 6	35	36	39	40	#N/A
36	University of North Carolina at Chapel Hill	36	39	36	33	31
37	University of British Columbia	37	40	34	31	43
38	The University of Manchester	38	41	35	38	34
39	The University of Texas at Austin	39	37	45	51	40
40	University of Copenhagen	40	35	30	30	29
41	University of California, Santa Barbara	41	38	42	45	46
42	University of Paris Sud (Paris 11)	42	42	46	41	42
43	University of Maryland, College Park	43	43	52	53	51
44	The University of Melbourne	44	44	40	39	38
45	The University of Edinburgh	45	47	41	32	33

Table A1, continued

	ARWU	2014	2015	2016	2017	2018
46	The University of Texas Southwestern Medical Center at Dallas	46	45	43	48	49
47	Karolinska Institute	47	48	44	44	44
48	University of California, Irvine	48	50	59	64	84
49	Heidelberg University	49	46	47	42	47
50	University of Munich	50	52	51	57	53
51	University of Southern California	51	49	49	54	60
52	Rutgers, The State University of New Jersey-New Brunswick	52	65	97	79	101–150
53	Technical University Munich	53	51	48	50	48
54	Vanderbilt University	54	53	61	52	50
55	University of California, Davis	55	57	76	87	98
56	University of Zurich	56	54	54	58	54
57	Utrecht University	57	56	66	47	52
58	Pennsylvania State University-University Park	58	60	77	86	75
59	King's College London	59	55	50	46	56
60	Purdue University-West Lafayette	60	62	64	77	72
61	Uppsala University	61	63	60	63	63
62	Carnegie Mellon University	62	61	68	81	91
63	University of Bristol	63	66	57	61	76
64	The Ohio State University-Columbus	64	68	80	82	94
65	University of Pittsburgh-Pittsburgh Campus	65	70	70	68	90
66	University of Geneva	66	58	53	60	59
67	Ecole Normale Superieure-Paris	67	72	87	69	64
68	McGill University	68	64	63	67	71
69	University of Oslo	69	59	67	62	62
70	Ghent University	70	71	62	70	61
71	The Hebrew University of Jerusalem	71	67	89	101–150	95
72	Boston University	72	74	75	80	70
73	University of Helsinki	73	69	56	56	58
74	Aarhus University	74	73	65	65	65
75	Brown University	75	75	90	101–150	101–150
76	The Australian National University	76	80	78	97	69
77	Leiden University	77	82	95	88	74
78	Osaka University	78	85	96	101–150	101–150
79	Stockholm University	79	78	81	75	77
80	Technion-Israel Institute of Technology	80	79	69	94	78
81	University of Florida	81	83	91	89	89
82	Rice University	82	84	73	74	73
83	University of Groningen	83	76	74	59	66
84	Moscow State University	84	86	88	93	88
85	The University of Queensland	85	81	55	55	55
86	University of Arizona	86	91	101–150	100	101–150
87	University of Utah	87	95	100	101–150	101–150
88	Arizona State University	88	93	101–150	101–150	101–150
89	The University of Western Australia	89	87	99	92	93
90	McMaster University	90	96	83	66	87
91	University of Basel	91	88	101–150	95	97

Table A1, continued

	ARWU	2014	2015	2016	2017	2018
92	University of Rochester	92	101–150	101–150	101–150	151–200
93	University of California, Santa Cruz	93	94	85	98	101–150
94	University of Bonn	94	97	101–150	101–150	101–150
95	University of Strasbourg	95	89	101–150	101–150	101–150
96	KU Leuven	96	90	94	90	86
97	Swiss Federal Institute of Technology Lausanne	97	101–150	92	76	82
98	Texas A & M University	98	101–150	101–150	101–150	151–200
99	Georgia Institute of Technology	99	101–150	93	85	80
100	VU University Amsterdam	100	98	101–150	101–150	101–150

Table A2
Dynamics of ranks in QS TOP-100, 2014–2018

	QS	2014	2015	2016	2017	2018
1	Massachusetts Institute of Technology (MIT)	1	1	1	1	1
2	University of Cambridge	2	3	4	5	6
3	Imperial College London	3	8	9	8	8
4	Harvard University	4	2	3	3	3
5	University of Oxford	5	6	6	6	5
6	UCL (University College London)	6	7	7	7	10
7	Stanford University	7	3	2	2	2
8	California Institute of Technology (Caltech)	8	5	5	4	4
9	Princeton University	9	11	11	13	13
10	Yale University	10	15	15	16	15
11	University of Chicago	11	10	10	9	9
12	ETH Zurich (Swiss Federal Institute of Technology)	12	9	8	10	7
13	University of Pennsylvania	13	18	18	19	19
14	Columbia University	14	22	20	18	16
15	Johns Hopkins University	15	16	17	17	21
16	King's College London (KCL)	16	19	21	23	31
17	University of Edinburgh	17	21	19	23	18
18	Ecole Polytechnique Fédérale de Lausanne	18	14	14	12	22
19	Cornell University	19	17	16	14	14
20	University of Toronto	20	34	32	31	28
21	McGill University	21	24	30	32	33
22	National University of Singapore (NUS)	22	12	12	15	11
23	University of Michigan	23	30	23	21	20
24	Ecole normale supérieure, Paris	24	23	33	43	#N/A
25	Australian National University	25	19	22	20	24
26	Duke University	26	29	25	21	26
27	University of California, Berkeley (UCB)	27	26	28	27	27
28	University of Hong Kong	28	30	27	26	25
29	University of Bristol	29	37	41	44	51
30	The University of Manchester	30	33	29	34	29
31	The University of Tokyo	31	39	34	28	23
32	Seoul National University	32	36	35	36	36
33	The University of Melbourne	33	42	42	41	39
34	Northwestern University	34	32	26	28	34

Table A2, continued

	QS	2014	2015	2016	2017	2018
35	Ecole Polytechnique	35	40	54	59	65
36	Kyoto University	36	38	37	36	35
37	University of California, Los Angeles (UCLA)	37	27	31	33	32
38	The University of Sydney	38	45	46	50	42
39	Nanyang Technological University (NTU)	39	13	13	11	12
40	The Hong Kong University of Science and Technology	40	28	36	30	37
41	New York University (NYU)	41	53	47	52	43
42	University of Wisconsin-Madison	42	54	53	55	53
43	University of British Columbia	43	50	45	51	47
44	The University of Queensland	44	46	51	47	48
45	University of Copenhagen	45	69	70	73	80
46	The Chinese University of Hong Kong	46	51	44	46	49
47	Tsinghua University	47	25	24	25	17
48	The University of New South Wales	48	46	49	45	45
49	Ruprecht-Karls-Universität Heidelberg	49	66	72	68	64
50	University of Amsterdam	50	55	57	58	57
51	KAIST-Korea Advanced Institute of Science & Technology	51	43	48	41	40
52	Ludwig-Maximilians-Universität München	52	75	68	66	62
53	Brown University	53	49	50	53	56
54	Technische Universität München	54	60	60	64	61
55	Osaka University	55	58	63	63	67
56	University of Glasgow	56	62	64	65	70
57	Peking University	57	41	39	38	30
58	University of Zurich	58	85	80	73	78
59	University of California, San Diego (UCSD)	59	44	40	38	41
60	Lund University	60	70	73	78	92
61	The University of Warwick	61	48	52	57	54
62	University of North Carolina, Chapel Hill	62	79	78	80	84
63	University of Illinois at Urbana-Champaign	63	59	66	69	71
64	University of Birmingham	64	76	82	84	79
65	University of Washington	65	65	59	61	66
66	Carnegie Mellon University	66	62	58	47	46
67	University of Helsinki	67	96	91	102	110
68	Tokyo Institute of Technology	68	56	56	56	58
69	The University of Sheffield	69	80	84	82	76
70	Monash University	70	67	65	60	59
71	Fudan University	71	51	43	40	44
72	London School of Economics and Political Science (LSE)	72	35	38	35	38
73	Tohoku University	73	74	75	76	77
74	Trinity College Dublin	74	78	100	88	104
75	Leiden University	75	95	102	109	122
76	National Taiwan University (NTU)	76	70	69	76	72
77	The University of Nottingham	77	70	76	84	82
78	Boston University	78	91	89	81	93
79	University of Texas at Austin	79	77	67	67	63
80	Utrecht University	80	94	104	109	124

Table A2, continued

	QS	2014	2015	2016	2017	2018
81	Uppsala University	81	102	98	112	117
82	KU Leuven	82	82	79	71	81
83	Université de Montréal	83	115	126	130	149
84	University of Alberta	84	96	94	90	109
85	University of Geneva	85	89	96	98	108
86	Delft University of Technology	86	64	62	54	52
87	Pohang University of Science And Technology (POSTECH)	87	87	83	71	83
88	University of St Andrews	88	68	77	92	97
89	The University of Western Australia	89	98	102	93	91
90	University of Groningen	90	100	113	113	120
91	Erasmus University Rotterdam	91	126	144	147	179
92	The University of Auckland	92	82	81	82	85
93	Durham University	93	61	74	78	74
94	University of Southampton	94	81	87	102	96
95	University of California, Davis	95	85	86	118	100
96	Aarhus University	96	107	117	119	141
97	University of Leeds	97	87	93	101	94
98	Queen Mary, University of London (QMUL)	98	109	123	127	119
99	Washington University in St. Louis	99	110	106	100	100
100	The University of Adelaide	100	113	125	109	114

Table A3
Dynamics of ranks in THE TOP-100, 2014–2018

	THE	2014	2015	2016	2017	2018
1	California Institute of Technology	1	1	2	3	5
2	Harvard University	2	6	6	6	6
3	University of Oxford	3	2	1	1	1
4	Stanford University	4	3	3	4	3
5	University of Cambridge	5	4	4	2	2
6	Massachusetts Institute of Technology	6	5	5	5	4
7	Princeton University	7	7	7	7	7
8	University of California, Berkeley	8	13	10	18	15
9	Imperial College London	9	8	8	8	9
10	Yale University	10	12	12	12	8
11	University of Chicago	11	10	11	9	10
12	University of California, Los Angeles	12	16	14	15	17
13	ETH Zurich	13	9	9	10	11
14	Columbia University	14	15	16	14	16
15	Johns Hopkins University	15	11	17	13	12
16	University of Pennsylvania	16	17	13	11	13
17	University of Michigan	17	21	21	21	20
18	Duke University	18	20	18	17	18
19	Cornell University	19	18	19	19	19
20	University of Toronto	20	19	22	23	21
21	Northwestern University	21	25	20	20	25
22	UCL	22	14	15	16	14
23	The University of Tokyo	23	43	39	46	42

Table A3, continued

	THE	2014	2015	2016	2017	2018
24	Carnegie Mellon University	24	22	23	24	24
25	National University of Singapore	25	26	24	22	23
26	University of Washington	26	32	26	26	28
27	Georgia Institute of Technology	27	41	33	33	34
28	University of Texas at Austin	28	46	50	49	39
29	LMU Munich	29	29	30	35	32
30	University of Illinois at Urbana-Champaign	30	36	37	37	50
31	University of Wisconsin-Madison	31	50	45	43	43
32	University of British Columbia	32	34	36	34	37
33	University of Melbourne	33	33	34	32	33
34	London School of Economics and Political Science	34	23	25	25	26
35	École Polytechnique Fédérale de Lausanne	35	31	31	38	35
36	University of Edinburgh	36	24	27	27	29
37	University of California, Santa Barbara	37	40	48	53	52
38	New York University	38	30	32	28	27
39	McGill University	39	38	42	42	44
40	King's College London	40	27	38	36	38
41	University of California, San Diego	41	39	41	31	30
42	Washington University in St Louis	42	61	58	51	54
43	University of Hong Kong	43	45	44	40	36
44	Karolinska Institute	44	28	28	39	40
45	Australian National University	45	52	47	48	49
46	University of Minnesota Twin Cities	46	66	53	56	71
47	University of North Carolina at Chapel Hill	47	63	56	57	56
48	Peking University	48	42	29	29	31
49	Tsinghua University	49	47	35	30	22
50	Seoul National University	50	85	73	75	63
51	Hong Kong University of Science and Technology	51	59	49	44	46
52	Korea Advanced Institute of Science and Technology (KAIST)	52	148	89	96	102
53	University of Manchester	53	56	55	55	57
54	Brown University	54	51	51	50	53
55	KU Leuven	55	35	40	47	48
56	University of California, Davis	56	44	52	54	59
57	Boston University	57	64	64	70	74
58	Pennsylvania State University	58	75	68	77	81
59	Kyoto University	59	88	92	74	65
60	University of Sydney	60	57	62	61	60
61	Nanyang Technological University, Singapore	61	55	54	52	51
62	École Polytechnique	62	101	116	115	108
63	Scuola Normale Superiore di Pisa	63	112	137	184	161
64	Leiden University	64	67	77	67	68
65	University of Queensland	65	60	60	65	69
66	Pohang University of Science and Technology	66	116	104	137	142
67	University of Göttingen	67	99	112	113	123
68	Ohio State University	68	92	72	71	72
69	Rice University	69	101	87	86	86
70	Heidelberg University	70	37	43	45	47
71	Delft University of Technology	71	65	59	63	58

Table A3, continued

	THE	2014	2015	2016	2017	2018
72	Erasmus University Rotterdam	72	71	69	72	70
73	Wageningen University & Research	73	48	65	64	61
74	University of Bristol	74	69	71	76	78
75	University of Basel	75	102	99	95	103
76	University of Southern California	76	68	61	66	66
77	University of Amsterdam	77	58	63	59	62
78	École Normale Supérieure(Paris)	78	54	66	#N/A	#N/A
79	Utrecht University	79	62	86	68	75
80	Humboldt University of Berlin	80	49	57	62	67
81	Free University of Berlin	81	72	75	88	104
82	Michigan State University	82	100	101	84	94
83	Durham University	83	70	96	97	114
84	Monash University	84	73	74	81	85
85	Middle East Technical University	85	501–600	601–800	601–800	601–800
86	University of Arizona	86	163	156	161	159
87	University of Notre Dame	87	108	143	150	173
88	Tufts University	88	127	135	169	152
89	University of California, Irvine	89	106	100	99	96
90	Ghent University	90	127	135	169	143
91	University of Massachusetts	91	141	165	191	201–250
92	University of Pittsburgh	92	79	81	101	110
93	Emory University	93	90	83	98	84
94	McMaster University	94	96	113	78	77
95	University of Glasgow	95	76	88	80	93
96	Vanderbilt University	96	87	108	105	121
97	University of Colorado Boulder	97	127	116	102	114
98	Stockholm University	98	136	144	134	153
99	Technical University of Munich	99	53	46	41	45
100	Uppsala University	100	81	93	87	88

Appendix 2

Table A4
Average ranks of universities in ARWU TOP-100 and the fluctuation range of in these ranks over five-year period (2014–2018)

	University	Average	Fluctuation range
1	Harvard University	1.0	0
2	Stanford University	2.0	0
3	Massachusetts Institute of Technology (MIT)	3.8	2
4	University of California-Berkeley	4.2	2
5	University of Cambridge	4.0	2
6	Princeton University	6.0	0
7	California Institute of Technology	8.0	2
8	Columbia University	8.2	1
9	University of Chicago	9.6	1
10	University of Oxford	8.2	3

Table A4, continued

	University	Average	Fluctuation range
11	Yale University	11.4	2
12	University of California, Los Angeles	11.8	1
13	Cornell University	13.0	2
14	University of California, San Diego	14.4	1
15	University of Washington	14.4	2
16	University of Pennsylvania	16.8	2
17	The Johns Hopkins University	17.0	2
18	University of California, San Francisco	20.0	3
19	Swiss Federal Institute of Technology Zurich	19.2	1
20	University College London	17.6	4
21	The University of Tokyo	21.6	4
22	The Imperial College of Science, Technology and Medicine	23.6	5
23	University of Michigan-Ann Arbor	24.0	5
24	University of Toronto	24.4	4
25	University of Wisconsin-Madison	26.6	4
26	Kyoto University	30.8	9
27	New York University	28.8	5
28	Northwestern University	25.8	6
29	University of Illinois at Urbana-Champaign	33.4	12
30	University of Minnesota, Twin Cities	32.8	7
31	Duke University	27.8	6
32	Washington University in St. Louis	25.6	12
33	Rockefeller University	33.8	7
34	University of Colorado at Boulder	37.6	9
35	Pierre and Marie Curie University-Paris 6	37.5	5
36	University of North Carolina at Chapel Hill	35.0	8
37	University of British Columbia	37.0	12
38	The University of Manchester	37.2	7
39	The University of Texas at Austin	42.4	14
40	University of Copenhagen	32.8	11
41	University of California, Santa Barbara	42.4	8
42	University of Paris Sud (Paris 11)	42.6	5
43	University of Maryland, College Park	48.4	10
44	The University of Melbourne	41.0	6
45	The University of Edinburgh	39.6	15
46	The University of Texas Southwestern Medical Center at Dallas	46.2	6
47	Karolinska Institute	45.4	4
48	University of California, Irvine	61.0	36
49	Heidelberg University	46.2	7
50	University of Munich	52.6	7
51	University of Southern California	52.6	11
52	Rutgers, The State University of New Jersey-New Brunswick	83.6	73
53	Technical University Munich	50.0	5
54	Vanderbilt University	54.0	11
55	University of California, Davis	74.6	43
56	University of Zurich	55.2	4
57	Utrecht University	55.6	19
58	Pennsylvania State University-University Park	71.2	28

Table A4, continued

	University	Average	Fluctuation range
59	King's College London	53.2	13
60	Purdue University-West Lafayette	67.0	17
61	Uppsala University	62.0	3
62	Carnegie Mellon University	72.6	30
63	University of Bristol	64.6	19
64	The Ohio State University-Columbus	77.6	30
65	University of Pittsburgh-Pittsburgh Campus	72.6	25
66	University of Geneva	59.2	13
67	Ecole Normale Superieure-Paris	71.8	23
68	McGill University	66.6	8
69	University of Oslo	63.8	10
70	Ghent University	66.8	10
71	The Hebrew University of Jerusalem	89.4	58
72	Boston University	74.2	10
73	University of Helsinki	62.4	17
74	Aarhus University	68.4	9
75	Brown University	98.0	50
76	The Australian National University	80.0	28
77	Leiden University	83.2	21
78	Osaka University	101.8	47
79	Stockholm University	78.0	6
80	Technion-Israel Institute of Technology	80.0	25
81	University of Florida	86.6	10
82	Rice University	77.2	11
83	University of Groningen	71.6	24
84	Moscow State University	87.8	9
85	The University of Queensland	66.2	30
86	University of Arizona	105.4	39
87	University of Utah	106.4	38
88	Arizona State University	111.2	37
89	The University of Western Australia	92.0	12
90	McMaster University	84.4	30
91	University of Basel	99.2	37
92	University of Rochester	118.4	83
93	University of California, Santa Cruz	98.4	40
94	University of Bonn	113.2	31
95	University of Strasbourg	111.4	36
96	KU Leuven	91.2	10
97	Swiss Federal Institute of Technology Lausanne	94.4	49
98	Texas A & M University	119.6	77
99	Georgia Institute of Technology	96.4	45
100	VU University Amsterdam	114.6	27

Table A5
Average ranks of universities in QS TOP-100 and the fluctuation range of in these ranks over five-year period (2014–2018)

No	University	Average	Fluctuation rangee
1	Massachusetts Institute of Technology (MIT)	1	0
2	University of Cambridge	4	4
3	Imperial College London	7.2	6
4	Harvard University	3	2
5	University of Oxford	5.6	1
6	UCL (University College London)	7.4	4
7	Stanford University	3.2	5
8	California Institute of Technology (Caltech)	5.2	4
9	Princeton University	11.4	4
10	Yale University	14.2	6
11	University of Chicago	9.8	2
12	ETH Zurich (Swiss Federal Institute of Technology)	9.2	5
13	University of Pennsylvania	17.4	6
14	Columbia University	18	8
15	Johns Hopkins University	17.2	6
16	King's College London (KCL)	22	15
17	University of Edinburgh	19.6	6
18	Ecole Polytechnique Fédérale de Lausanne	16	10
19	Cornell University	16	5
20	University of Toronto	29	14
21	McGill University	28	12
22	National University of Singapore (NUS)	14.4	11
23	University of Michigan	23.4	10
24	Ecole normale supérieure, Paris	30.75	20
25	Australian National University	22	6
26	Duke University	25.4	8
27	University of California, Berkeley (UCB)	27	2
28	University of Hong Kong	27.2	5
29	University of Bristol	40.4	22
30	The University of Manchester	31	5
31	The University of Tokyo	31	16
32	Seoul National University	35	4
33	The University of Melbourne	39.4	9
34	Northwestern University	30.8	8
35	Ecole Polytechnique	50.6	30
36	Kyoto University	36.4	3
37	University of California, Los Angeles (UCLA)	32	10
38	The University of Sydney	44.2	12
39	Nanyang Technological University (NTU)	17.6	28
40	The Hong Kong University of Science and Technology	34.2	12
41	New York University (NYU)	47.2	12
42	University of Wisconsin-Madison	51.4	13
43	University of British Columbia	47.2	8
44	The University of Queensland	47.2	7
45	University of Copenhagen	67.4	35
46	The Chinese University of Hong Kong	47.2	7
47	Tsinghua University	27.6	30
48	The University of New South Wales	46.6	4

Table A5, continued

No	University	Average	Fluctuation rangee
49	Ruprecht-Karls-Universität Heidelberg	63.8	23
50	University of Amsterdam	55.4	8
51	KAIST-Korea Advanced Institute of Science & Technology	44.6	11
52	Ludwig-Maximilians-Universität München	64.6	23
53	Brown University	52.2	7
54	Technische Universität München	59.8	10
55	Osaka University	61.2	12
56	University of Glasgow	63.4	14
57	Peking University	41	27
58	University of Zurich	74.8	27
59	University of California, San Diego (UCSD)	44.4	21
60	Lund University	74.6	32
61	The University of Warwick	54.4	13
62	University of North Carolina, Chapel Hill	76.6	22
63	University of Illinois at Urbana-Champaign	65.6	12
64	University of Birmingham	77	20
65	University of Washington	63.2	7
66	Carnegie Mellon University	55.8	20
67	University of Helsinki	93.2	43
68	Tokyo Institute of Technology	58.8	12
69	The University of Sheffield	78.2	15
70	Monash University	64.2	11
71	Fudan University	49.8	31
72	London School of Economics and Political Science (LSE)	43.6	37
73	Tohoku University	75	4
74	Trinity College Dublin	88.8	30
75	Leiden University	100.6	47
76	National Taiwan University (NTU)	72.6	7
77	The University of Nottingham	77.6	14
78	Boston University	86.4	15
79	University of Texas at Austin	70.6	16
80	Utrecht University	102.2	44
81	Uppsala University	102	36
82	KU Leuven	79	11
83	Université de Montréal	120.6	66
84	University of Alberta	94.6	25
85	University of Geneva	95.2	23
86	Delft University of Technology	63.6	34
87	Pohang University of Science And Technology (POSTECH)	82.2	16
88	University of St Andrews	84.4	29
89	The University of Western Australia	94.6	13
90	University of Groningen	107.2	30
91	Erasmus University Rotterdam	137.4	88
92	The University of Auckland	84.4	11
93	Durham University	76	32
94	University of Southampton	96.8	21
95	University of California, Davis	97	33
96	Aarhus University	116	45
97	University of Leeds	94.4	14
98	Queen Mary, University of London (QMUL)	115.2	29

Table A5, continued

No	University	Average	Fluctuation rangee
99	Washington University in St. Louis	103	11
100	The University of Adelaide	112.2	25

Table A6
Average ranks of universities in THE TOP-100 and the fluctuation range of in these ranks over five-year period (2014–2018)

No	University	Average	Fluctuation rangee
1	California Institute of Technology	2.4	4
2	Harvard University	5.2	4
3	University of Oxford	1.6	2
4	Stanford University	3.4	1
5	University of Cambridge	3.4	3
6	Massachusetts Institute of Technology	5.0	2
7	Princeton University	7.0	0
8	University of California, Berkeley	12.8	10
9	Imperial College London	8.4	1
10	Yale University	10.8	4
11	University of Chicago	10.2	2
12	University of California, Los Angeles	14.8	5
13	ETH Zurich	10.4	4
14	Columbia University	15.0	2
15	Johns Hopkins University	13.6	6
16	University of Pennsylvania	14.0	6
17	University of Michigan	20.0	4
18	Duke University	18.2	3
19	Cornell University	18.8	1
20	University of Toronto	21.0	4
21	Northwestern University	22.2	5
22	UCL	16.2	8
23	The University of Tokyo	38.6	23
24	Carnegie Mellon University	23.4	2
25	National University of Singapore	24.0	4
26	University of Washington	27.6	6
27	Georgia Institute of Technology	33.6	14
28	University of Texas at Austin	42.4	22
29	LMU Munich	31.0	6
30	University of Illinois at Urbana-Champaign	38.0	20
31	University of Wisconsin-Madison	42.4	19
32	University of British Columbia	34.6	5
33	University of Melbourne	33.0	2
34	London School of Economics and Political Science	26.6	11
35	École Polytechnique Fédérale de Lausanne	34.0	7
36	University of Edinburgh	28.6	12
37	University of California, Santa Barbara	46.0	16
38	New York University	31.0	11
39	McGill University	41.0	6
40	King's College London	35.8	13
41	University of California, San Diego	36.4	11

Table A6, continued

No	University	Average	Fluctuation rangee
42	Washington University in St Louis	53.2	19
43	University of Hong Kong	41.6	9
44	Karolinska Institute	35.8	16
45	Australian National University	48.2	7
46	University of Minnesota Twin Cities	58.4	25
47	University of North Carolina at Chapel Hill	55.8	16
48	Peking University	35.8	19
49	Tsinghua University	36.6	27
50	Seoul National University	69.2	35
51	Hong Kong University of Science and Technology	49.8	15
52	Korea Advanced Institute of Science and Technology (KAIST)	97.4	96
53	University of Manchester	55.2	4
54	Brown University	51.8	4
55	KU Leuven	45.0	20
56	University of California, Davis	53.0	15
57	Boston University	65.8	17
58	Pennsylvania State University	71.8	23
59	Kyoto University	75.6	33
60	University of Sydney	60.0	5
61	Nanyang Technological University, Singapore	54.6	10
62	École Polytechnique	100.4	54
63	Scuola Normale Superiore di Pisa	131.4	121
64	Leiden University	68.6	13
65	University of Queensland	63.8	9
66	Pohang University of Science and Technology	113.0	76
67	University of Göttingen	102.8	56
68	Ohio State University	75.0	24
69	Rice University	85.8	32
70	Heidelberg University	48.4	33
71	Delft University of Technology	63.2	13
72	Erasmus University Rotterdam	70.8	3
73	Wageningen University & Research	62.2	25
74	University of Bristol	73.6	9
75	University of Basel	94.8	28
76	University of Southern California	67.4	15
77	University of Amsterdam	63.8	19
78	Íęcole Normale Supérieure	66.0	24
79	Utrecht University	74.0	24
80	Humboldt University of Berlin	63.0	31
81	Free University of Berlin	84	32
82	Michigan State University	92.2	19
83	Durham University	92.0	44
84	Monash University	79.4	12
85	Middle East Technical University	547.0	615
86	University of Arizona	145.0	77
87	University of Notre Dame	132.2	86
88	Tufts University	134.2	81
89	University of California, Irvine	98.0	17
90	Ghent University	132.8	79
91	University of Massachusetts	162.6	134

Table A6, continued

No	University	Average	Fluctuation rangee
92	University of Pittsburgh	92.6	31
93	Emory University	89.6	15
94	McMaster University	91.6	36
95	University of Glasgow	86.4	19
96	Vanderbilt University	103.4	34
97	University of Colorado Boulder	111.2	30
98	Stockholm University	133.0	55
99	Technical University of Munich	56.8	58
100	Uppsala University	89.8	19