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The influences of counting methods on university rankings based on paper count and citation count

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ABSTRACT

In an age of intensifying scientific collaboration, the counting of papers by multiple authors has become an important methodological issue in scientometric based research evaluation. Especially, how counting methods influence institutional level research evaluation has not been studied in existing literatures. In this study, we selected the top 300 universities in physics in the 2011 HEEACT Ranking as our study subjects. We compared the university rankings generated from four different counting methods (i.e. whole counting, straight counting using first author, straight counting using corresponding author, and fractional counting) to show how paper counts and citation counts and the subsequent university ranks were affected by counting method selection. The counting was based on the 1988–2008 physics papers records indexed in ISI WoS. We also observed how paper and citation counts were inflated by whole counting. The results show that counting methods affected the universities in the middle range more than those in the upper or lower ranges. Citation counts were also more affected than paper counts. The correlation between the rankings generated from whole counting and those from the other methods were low or negative in the middle ranges. Based on the findings, this study concluded that straight counting and fractional counting were better choices for paper count and citation count in the institutional level research evaluation.

1. Introduction

In recent decades, scientists have intensified research collaboration. Consequently, counting co-authored papers has constituted a methodological problem in informatrics based research evaluation. Previous studies have addressed the problems and influences of counting methods in country-level research evaluation (e.g., Gauffriau & Larsen, 2005a, 2005b; Gauffriau, Larsen, Maye, Roulin-Perriard, & von Ins, 2007; Gauffriau, Larsen, Maye, Roulin-Perriard, & von Ins, 2008; Huang, Lin, & Chen, 2011; Larsen, 2007a, 2007b). But how counting methods affect institution level research evaluation has hardly been reported in existing literatures. This study addresses the knowledge gap by testing four different counting methods on a large bibliometric dataset to see how university rankings are influenced by counting method choices.

University ranking is a quantitative style of university performance evaluation (Huang, 2011). Today, several large-scale university ranking programs exist. Most of them rely partly or wholly on bibliometric measures (Aguillo, Bar-Ilan, Levene, & Ortega, 2010). Paper count and citation count are respectively the two most basic bibliometric indicators for assessing research productivity and impact. The invent of the measures for research evaluation may be attributed to the

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groundbreaking work of Eugene Garfield, who envisioned the use of objective and countable citations as the basis for studying research impact in 1955, and who later materialized Science Citation Index (SCI), Social Science Citation Index (SSCI), and other tools since 1958 that made the analyses possible (Garfield, 2006; Garfield & Sher, 1963).

Today, few ranking programs employ such simple and primitive indicators as the sole basis for measuring research performances. But paper count and citation count continue to be the foundation for the more sophisticated measures (Academic Ranking of World Universities [ARWU], 2011; Higher Education Evaluation and Accreditation Council of Taiwan [HEEACT], 2010; Leiden Ranking, 2012; NTU Ranking, 2012). As such, the original numbers of papers and citations may still influence performance rankings. In a previous study, we tested three counting approaches on a large dataset to observe their influences on the country-level rankings (citation temporarily removed for review). In this study, the counting methods were again tested to see how institutional level rankings were influenced accordingly. The focus of this study is not to evaluate the research performance of the universities included in our data, but to observe how the selection of counting methods influence the paper counts and citation counts for the universities and how rank positions of the universities are changed by that.

Our data were the paper and citation records in the field of physics between January, 1989 and August, 2008 as indexed in Thomson Reuter's Web of Science (WOS). We focused on 300 universities which have excelled in physics research. One problem with the use of WOS data in institution level analyses is that, over years, authors' institutions have been indexed inconsistently in the database. The "unification of institution names" (Van Raan, 2005) must be conducted before the data can be used for analyses. We employed the concept of "authority control" (Taylor, 2004) on the original WOS records to ensure the data accuracy. The procedures for the authority control work will be reported in Section 3.

2. Counting methods for university rankings

The ways in which collaborative papers are counted can affect the numbers of papers and citations attributed to a university. Huang et al. (2011) summarized three different counting approaches. The first is *whole counting*. Depending on the level of evaluation, each unique collaborating institution or country receives one full credit (Gauffriau et al., 2007, 2008). It is also the de facto method for several well-known global university ranking programs (ARWU, 2011; Quacquarelli Symonds [QS], 2011; HEEACT, 2010; NTU Ranking, 2012).

The second approach is *straight counting*. Only the most prominent collaborator receives one full credit, and the others receive none. *First author counting* and *corresponding author counting* are characteristic of this approach. Both have been used in previous biblimetric studies (Gauffriau & Larsen, 2005a, 2005b; Larsen, 2007a, 2007b). The idea behind the two highly similar methods was the same, i.e. to credit the main leader only. The SCImago Group therefore used the term "leadership" for this type of counting (SCImago Journal & Country Rank [SJR], 2012).

The third is *fractional counting*. One credit is equally or proportionally shared by the collaborators (Gauffriau & Larsen, 2005a; Gauffriau et al., 2007, 2008). The Leiden Ranking by the Centre for Science and Technology Studies (CWTS) in Leiden University, Netherlands, is a current university ranking program that supports fractional counting (Leiden Ranking, 2012).

All of these counting methods are simple and straightforward enough to be used in large-scale ranking programs. But whole counting unavoidably generates larger numbers than the other methods; the sum of each university's paper and citation count by this method also exceeds the total number of papers/citations there actually are. In other words, whole counting inflates paper and citation counts. Huang et al. (2011) found that, in the country level research evaluation, certain countries have systematically benefited from such inflation and received better ranking positions from using it. By the same token, we can expect to see some universities benefit from whole counting in institution level evaluation.

However, Huang et al. (2011) also found that, at the country level, country rankings from different counting methods were highly correlated, which suggests that counting methods were of minor influence on the overall ranking results. But at the institution level, counting methods are more likely to have a stronger impact on ranking because the difference between two universities' papers and citation numbers are usually smaller than those of two countries. As such, altering counting methods may change two universities' rank positions. Moreover, the number of universities in the world is much larger than the number of countries. There are more universities having similar quantity of papers and citations, and their collaboration with other institutions may vary. Consequently, we may predict that more counting method-induced rank changes will occur at the institution level.

We thus tested four counting methods on a large bibliometric dataset to see whether the prediction holds. Our research questions included whether different counting methods generate alternative university rankings as well as how and to what extent the ranking results vary. We focused only on the rankings of universities and excluded independent research institutions. The counting methods we tested included:

a. Whole counting (W): each collaborating university of a paper receives one full credit.
b. Straight counting using the first author (SF): only the first author's university receives one full credit, and the other collaborating universities receive none.
c. Straight counting using the corresponding author (SC): only the corresponding author's university receives one full credit, and the other collaborating universities receive none.
d. Fractional counting (F): each collaborating university of a paper equally shares one credit.

3. Methodology

3.1. The study subjects

Our study subjects were the top 300 universities in the field of physics as in the HEEACT 2010 Performance Ranking (HEEACT, 2011). During January, 1989 to August, 2008, these 300 universities had together produced 1,400,991 papers and received 16,904,969 citations. The WOS database contained 1,445,273 physics papers and 17,005,626 citations for the same period of time. That is, our study subjects had accounted for 96.94% of the paper production and 99.41% of the citations in the physics field.

It should be noted that the Université Libre de Bruxelles of Belgium was in the HEEACT top 300 list, but it was dropped from our analyses because we were unable to completely differentiate it with another university, Vrije Universiteit Brussel. The two universities are located in the same city and their names could be identical in certain forms. For better validity, we excluded it from the analyses. Consequently a total of 299 universities were examined in this study.

3.2. Data processing

The original WOS data cannot be used for institution level analyses for several reasons. First, the author affiliation information in the original records was chaotic. Institution names and institution information were not always recorded in a consistent format. Moreover, the same institutions could be referred to in different ways (e.g., by the official, full institution name and/or by varying forms of abbreviations).

Secondly, different authors have given their affiliation information at different institution levels. For example, a paper may have supplied the university name only, while another has supplied both the university and the department names; in some instances the sub-unit names (e.g., a university hospital or research center under a parent university) were given without the parent university's name. But the more problematic condition for university level analyses is when authors from large university systems failed to explicitly indicate their affiliated campuses. A number of university systems are composed of individual campuses that are defined as academically autonomous universities in this study, e.g., the Urbana-Champaign, Chicago, and Springfield campuses of the University of Illinois. Authors from those different campuses did not always supply their affiliations at the campus level.

We conducted authority control of institutions to solve the problems. The control was set at the university/campus level – campuses of the state university systems were treated as individual universities. Our research team systematically identified all possible forms of a university's name from the WOS records. Wildcard and truncation were used to assist in name identification and to enhance recall of records. Retrieved records with confusing names (e.g., same abbreviations, different institutions) were manually inspected to ensure that they were classified under the right university. To differentiate papers from different campuses of a large university system when the campus was not clearly indicated, we further relied on the author addresses in the records to make judgments. The result was a name authority file of more than 700 universities that were used to automatically re-classify papers and citations under each university at the university level. Papers and citations of the top 300 universities in physics were retrieved for the current analyses.

4. University rank changes

4.1. Paper counts

To observe how ranking was affected by counting method at institution level, we selected three groups of universities occupying 30 consecutive positions in the top, middle, and bottom parts of the top 300 universities. Tables 1–3 show the paper counts and rank positions of each university whose rank by whole counting was within 1–30, 136–165, and 270–299. The top 13 universities formed a cohort that was barely affected by counting method. There were three clusters in which university ranks were interchangeable by varying counting methods (Table 1). However, rank position changes grew larger beyond the 13 universities and the clustering phenomenon was not observed until it went to the bottom of the list (Table 3). Clusters formed among the outlier universities whose paper production was exceptionally high or low so the choice of counting methods did not effect their rank positions much.

Rank changes were particularly intense in the middle range of the universities. As the tables show, the rank changes resulted from counting method use were all lower than 15 positions among the top 30 universities. But the position differences became larger among the top 136–165 universities: over 2/3 of these universities experienced a change of more than 15 positions. Some universities rose or dropped dramatically by altering counting methods, e.g., University Louise Pasteur (Strasbourg I), Indian Institute of Science, National Cheng Kung University (Table 2). Comparing the three tables, counting methods affected the middle-ranged universities more than those in the upper and lower ends.

4.2. Citation counts

Similar to what we observed in paper count, we saw two rank-interchangeable clusters in the rather stable top 10 universities by citation count. Beyond that, rankings varied by counting methods. For the upper-ranged universities, counting

Table 1
Paper counts, university ranks, and counting inflation by different counting methods: the top 1–30 universities.

Institution	1989–2008 paper count by different counting method				Rank by paper count				Counting inflation ratio[a]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
The University of Tokyo	21,879	12,200	11,751	11706.06	1	1	1	1	1.79	1.86	1.87
Tohoku University	14,359	7811	7803	7744.45	2	3	2	2	1.84	1.84	1.85
MIT	13,286	7877	7662	7493.05	3	2	3	3	1.69	1.73	1.77
Osaka University	12,440	7487	7508	6937.66	4	4	5	6	1.66	1.66	1.79
Kyoto University	12,251	7193	7108	7011.45	5	6	6	5	1.70	1.72	1.75
University of Cambridge	11,932	7469	7562	7380.56	6	5	4	4	1.60	1.58	1.62
University of California – Berkeley	11,642	6246	6331	6054.42	7	8	7	8	1.86	1.84	1.92
University of Paris XI: Sud	11,486	5136	5140	5237.72	8	11	12	11	2.24	2.23	2.19
Lomonosov Moscow State University	10,249	6248	6163	6200.26	9	7	8	7	1.64	1.66	1.65
University of Oxford	9474	5091	5149	5009.43	10	12	11	12	1.86	1.84	1.89
University of Illinois – Urbana-Champaign	9279	5755	5534	5451.52	11	9	9	9	1.61	1.68	1.70
Stanford University	9017	5539	5459	5393.39	12	10	10	10	1.63	1.65	1.67
Princeton University	8730	4862	4934	4765.24	13	13	13	13	1.80	1.77	1.83
Tokyo Institute of Technology	8217	4651	4639	4536.95	14	14	16	15	1.77	1.77	1.81
University of Paris VI: Pierre et Marie Curie	8208	3749	3716	3580.53	15	28	29	29	2.19	2.21	2.29
University of Maryland – College Park	8102	4265	4295	4326.23	16	20	19	17	1.90	1.89	1.87
California Institute of Technology	7883	4620	4761	4610.23	17	15	14	14	1.71	1.66	1.71
University of California – Santa Barbara	7790	4310	4201	4406.22	18	18	21	16	1.81	1.85	1.77
Imperial College London	7555	4238	4336	4195.59	19	21	18	20	1.78	1.74	1.80
University of Michigan – Ann Arbor	7068	3932	3968	3877.58	20	23	24	23	1.80	1.78	1.82
University of Science and Technology of China	6982	4297	4280	4198.24	21	19	20	19	1.62	1.63	1.66
University of California – Los Angeles	6854	3866	3810	3733.07	22	25	27	24	1.77	1.80	1.84
University of California – San Diego	6758	3770	3667	3657.22	23	27	30	27	1.79	1.84	1.85
Swiss Federal Institute of Technology – Zurich	6757	3692	3823	3534.75	24	30	26	30	1.83	1.77	1.91
University of Sao Paulo	6719	3852	3891	3697.78	25	26	25	25	1.74	1.73	1.82
University of Wisconsin – Madison	6466	3300	3417	3335.60	26	34	33	33	1.96	1.89	1.94
Nagoya University	6460	3744	3773	3517.94	27	29	28	31	1.73	1.71	1.84
Tsinghua University	6407	4613	4658	4264.34	28	16	15	18	1.39	1.38	1.50
Harvard University	6353	3309	3276	3238.82	29	33	34	34	1.92	1.94	1.96
The University of Texas – Austin	6183	4031	4053	3992.58	30	22	22	21	1.53	1.53	1.55

[a] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

methods again did not result in huge rank changes except for the University of Ohio at Columbus (ranked 30th by whole counting) (Table 4). But for the middle and lower ranges, counting methods have brought about more serious rank changes. 28 universities experienced a rise/drop of over 15 positions (compared to 23 universities in paper count), and 7 universities' rank differences were larger than 60 positions. The University of Genoa and University of Hawaii-Manoa even dropped more than 100 positions from whole counting to straight counting; the Scuola Normale Superiore di Pisa dropped 99 (see Table 5). Rank changes became less dramatic in universities ranked 270–299 (Table 6). But compared to what was seen in paper count, counting methods still produced greater rank differences for the universities in the lower range.

4.3. Correlation and differences of the rankings resulted from different counting methods

In the previous sections we used three sets of samples, each comprising approximately 30 universities, to demonstrate how universities occupying the upper, middle, and lower positions in the top 300 list were affected by counting methods, especially whole counting. To determine to what extent counting methods may have influenced ranking, we continued to examine the correlation and difference of the rankings generated from different methods.

Table 7 shows that, when the entire top 300 universities were ranked by different counting methods, the correlation between rankings from any two methods was actually very high (>.944 at the significance level of $p < 0.01$). This means that the selection of counting methods did not obscure the global trend much in terms of knowing how well the universities performed relative to each other.

However, when we continued to observe the correlation at different thresholds, we found that the correlation of whole counting with other counting methods dropped in the middle range ($\leq$.442 for the top 101–200 universities; $\leq$.595 for the top 51–250 universities when zoned by 50). The correlation was particularly low between the top 100 and 200. When the sample size was further reduced to 30 universities, we see that whole counting becomes barely or negatively correlated with the other methods for the middle-range sample (the top 136–135). In contrast, the correlation of the other three methods was always higher than .9 at the .01 significance level no matter how small the sample was. A nearly identical trend was observed in citation counts-based rankings. This means that the choice of counting methods impacts mainly the middle-ranged universities. Straight counting (based on first author or corresponding author) and fractional counting yield more consistent ranking results than whole counting.

Table 2
Paper counts, university ranks, and counting inflation by different counting methods: the top 136–165 universities.

Institution	1989–2008 paper count by different counting method				Rank by paper count[a]				Counting inflation ratio[b]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
Durham University	3098	1934	1914	1885.70	136	99	103	99	1.60	1.62	1.64
University of Cologne	3089	1633	1674	1597.49	137	135	133	135	1.89	1.85	1.93
Ecole normale superieure	3087	1622	1713	1546.32	138	136	125	141	1.90	1.80	2.00
Helsinki University of Technology	3059	1861	1927	1685.94	139	106	101	124	1.64	1.59	1.81
University of Sheffield	3040	1674	1576	1685.65	140	127	142	125	1.82	1.93	1.80
Charles University in Prague	3028	1272	1312	1225.10	141	185	184	189	2.38	2.31	2.47
University Louis Pasteur (Strasbourg I)	2995	1157	1155	1202.03	142	207	213	196	2.59	2.59	2.49
Korea University	2990	1315	1322	1189.68	143	183	182	199	2.27	2.26	2.51
Freie Universitat Berlin	2973	1747	1713	1735.05	144	120	125	119	1.70	1.74	1.71
Technical University of Denmark	2970	1746	1690	1736.92	145	121	128	117	1.70	1.76	1.71
The University of Sydney	2951	1793	1816	1746.06	146	115	114	115	1.65	1.63	1.69
University of Alberta	2947	1572	1638	1557.74	147	142	137	139	1.87	1.80	1.89
University of Birmingham	2936	1365	1363	1289.78	148	173	177	181	2.15	2.15	2.28
North Carolina State University	2929	1869	1855	1794.31	149	104	108	105	1.57	1.58	1.63
The Hebrew University of Jerusalem	2915	1817	1864	1754.79	150	110	107	111	1.60	1.56	1.66
Yonsei University	2912	1581	1587	1424.00	151	141	140	161	1.84	1.83	2.04
University of Vienna	2897	1652	1725	1600.56	152	130	122	134	1.75	1.68	1.81
University of Southern California	2881	1899	1891	1891.76	153	102	104	98	1.52	1.52	1.52
University of Rome Tor Vergata	2870	1197	1233	1142.03	154	204	199	206	2.40	2.33	2.51
Universite de Montreal	2861	1613	1567	1561.65	155	138	144	137	1.77	1.83	1.83
Indian Institute of Science	2859	2025	2030	1931.67	156	94	94	95	1.41	1.41	1.48
Universidade Tecnica de Lisboa	2804	1374	1411	1328.56	157	171	169	174	2.04	1.99	2.11
Waseda University	2781	1486	1473	1430.41	158	151	158	159	1.87	1.89	1.94
Humboldt University of Berlin	2775	1526	1544	1473.34	159	147	146	152	1.82	1.80	1.88
University of California - Irvine	2759	1539	1509	1532.90	160	146	152	143	1.79	1.83	1.80
National Cheng Kung University	2757	1992	2074	1784.63	161	96	93	107	1.38	1.33	1.54
Eberhard Karls University of Tubingen	2733	1622	1729	1619.88	162	136	120	129	1.68	1.58	1.69
Eindhoven University of Technology	2719	1769	1723	1736.28	163	117	123	118	1.54	1.58	1.57
McMaster University	2708	1643	1650	1619.33	164	131	136	130	1.65	1.64	1.67
University of Melbourne	2698	1642	1685	1608.12	165	133	129	133	1.64	1.60	1.68

[a] The different graying levels of the background indicate the degrees of rank position changes (<15, 16–30, 30–60, >60).
[b] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

Given that the rankings were highly correlated, the comparative analysis (Pickvance, 2001; Poh, Ang, & Bai, 2001) of the rankings revealed that, counting methods did result in significant differences. When the entire top 300 universities were compared, the differences of the methods all archived significance at the $p < 0.001$ level both in paper count and citation count. The differences of the three major counting approaches (whole counting, straight counting, and fractional counting) are also apparent. A noteworthy observation is the difference between SF and SC. Counting first author and counting corresponding author were of no significant difference in certain thresholds, e.g., 1–50 and 1–100 in paper count; 201–300 in citation count. But beyond these particular thresholds, the differences between the two methods were all significant at the $p < 0.001$ or <0.01 levels. This means that even the selection of the first author or corresponding author can influence university rankings.

4.4. Counting inflation

For each university in Tables 1–6, we divided the whole counting number by the numbers respectively from the other three counting methods to see how the former inflated a university's paper production and citation impact. The results showed that, in paper count, the inflation ratios for most of the upper-ranged universities were between 1.50 and 2.00. Paper numbers were further inflated in the middle range. 18 middle-ranged universities received an inflation ratio higher than 1.75. The lower range saw the biggest inflation; two universities' paper numbers were inflated more than three times (Tables 1–3).

In citation count, the numbers were inflated more by whole counting than by paper count. As Tables 4–6 show, only a small number of universities had an inflation ratio less than 1.75. Most of the upper-rangers' citation counts got inflated twice; and for many universities of the middle and lower ranges, citation counts got inflated three times. Some universities even saw inflation 5–6 times larger, e.g., University of Genoa, University of Hawaii-Manoa (Table 5), George Mason University, University of Victoria, University of Ferrara (Table 6).

It was not surprising to see extremely high inflation in the lower-ranged universities because inflation ratio is not only influenced by counting methods, but also by numbers. Universities in the lower portion of the list produced smaller numbers of papers and citations, and the inflation ratios became more sensitive to the different counting methods. Although higher counting inflation did not necessarily predict larger position changes or even the change directions, an exceptionally high

Table 3
Paper counts, university ranks, and counting inflation by different counting methods: the top 270–299 universities.

Institution	1989–2008 paper count by different counting method				Rank by paper count[a]				Counting inflation ratio[b]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
University of South Carolina	1284	573	557	554.95	270	271	273	270	2.24	2.31	2.31
Ecole normale superieure de Lyon	1283	650	652	661.64	271	264	266	262	1.97	1.97	1.94
University of Granada	1269	831	840	788.25	272	245	245	249	1.53	1.51	1.61
Case Western Reserve University	1244	803	813	785.49	273	250	250	250	1.55	1.53	1.58
University of Crete	1183	454	464	495.11	274	277	277	276	2.61	2.55	2.39
Kent State University	1176	581	573	545.87	275	269	272	271	2.02	2.05	2.15
University of Ferrara	1153	437	455	416.50	276	281	278	282	2.64	2.53	2.77
Carleton University	1098	285	266	274.21	277	290	293	292	3.85	4.13	4.00
Oklahoma State University	1097	632	651	588.02	278	267	267	268	1.74	1.69	1.87
College of William and Mary	1066	493	483	470.44	279	276	276	277	2.16	2.21	2.27
Colorado State University	1039	640	676	617.81	280	266	262	266	1.62	1.54	1.68
Cardiff University	1032	662	673	635.94	281	263	264	264	1.56	1.53	1.62
Monash University	1007	719	738	687.12	282	261	258	261	1.40	1.36	1.47
Universite d'Auvergne	1006	270	278	275.72	283	293	292	291	3.73	3.62	3.65
University of Bergen	992	346	372	324.49	284	286	286	288	2.87	2.67	3.06
University of Victoria	967	399	387	386.86	285	283	284	284	2.42	2.50	2.50
The George Washington University	915	387	393	414.46	286	284	283	283	2.36	2.33	2.21
University of London – Royal Holloway College	855	340	338	355.41	287	287	288	286	2.51	2.53	2.41
New Mexico State University	813	340	352	350.66	288	287	287	287	2.39	2.31	2.32
Drexel University	807	440	430	447.82	289	278	281	279	1.83	1.88	1.80
University of Porto	780	375	381	356.16	290	285	285	285	2.08	2.05	2.19
The University of Mississippi	639	274	282	268.21	291	292	291	293	2.33	2.27	2.38
George Mason University	635	233	250	250.75	292	294	294	294	2.73	2.54	2.53
University of Leicester	561	307	326	309.03	293	289	289	289	1.83	1.72	1.82
Pontificia Universidad Catolica de Chile	492	282	293	287.33	294	291	290	290	1.74	1.68	1.71
The Catholic University of America	354	174	169	165.60	295	296	296	296	2.03	2.09	2.14
Rochester Institute of Technology	339	215	228	226.94	296	295	295	295	1.58	1.49	1.49
University of Wyoming	164	73	80	79.89	297	299	298	298	2.25	2.05	2.05
University of Hertfordshire	138	87	86	84.13	298	297	297	297	1.59	1.60	1.64
Liverpool John Moores University	99	75	72	66.38	299	298	299	299	1.32	1.38	1.49

[a] The different graying levels of the background indicate the degrees of rank position changes (<15, 16–30, 30–60, >60).
[b] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

Table 4
Citation counts, university ranks, and counting inflation by different counting methods: the top 1–30 universities.

Institution	1989–2008 citation count by different counting method				Rank by citation count[a]				Counting inflation ratio[b]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
Massachusetts Institute of Technology	379,845	206,342	207,192	201072.37	1	1	1	1	1.84	1.83	1.89
The University of Tokyo	375,435	200,862	193,603	181404.30	2	2	2	2	1.87	1.94	2.07
Stanford University	281,828	160,128	157,586	151715.26	3	3	3	3	1.76	1.79	1.86
University of California – Berkeley	276,571	136,918	142,558	128664.39	4	7	6	7	2.02	1.94	2.15
University of California – Santa Barbara	255,084	140,043	138,411	138975.08	5	5	7	4	1.82	1.84	1.84
University of Cambridge	247,660	139,513	145,477	138375.44	6	6	5	5	1.78	1.70	1.79
Princeton University	246,762	141,165	146,139	129165.51	7	4	4	6	1.75	1.69	1.91
University of Illinois – Urbana–Champaign	228,519	131,778	127,163	121616.94	8	8	8	8	1.73	1.80	1.88
California Institute of Technology	214,076	111,035	112,632	108431.04	9	9	9	9	1.93	1.90	1.97
Tohoku University	212,072	97,585	102,803	97117.11	10	11	11	11	2.17	2.06	2.18
Harvard University	206,992	108,194	108,901	106268.55	11	10	10	10	1.91	1.90	1.95
University of Paris XI: Sud	199,600	79,902	83,610	83898.84	12	19	16	13	2.50	2.39	2.38
University of Oxford	179,421	79,935	85,217	82151.64	13	18	14	14	2.24	2.11	2.18
University of Maryland – College Park	172,816	80,878	80,405	79695.61	14	17	18	18	2.14	2.15	2.17
University of California – San Diego	167,195	84,853	83,649	80011.38	15	13	15	17	1.97	2.00	2.09
University of California – Los Angeles	165,179	83,398	78,559	76695.07	16	16	20	20	1.98	2.10	2.15
Kyoto University	164,697	84,115	86,286	86716.27	17	15	12	12	1.96	1.91	1.90
Osaka University	164,089	85,465	86,263	81006.34	18	12	13	16	1.92	1.90	2.03
University of Washington – Seattle	151,574	61,055	65,046	61949.39	19	25	25	25	2.48	2.33	2.45
Cornell University	150,940	84,848	82,281	81943.27	20	14	17	15	1.78	1.83	1.84
Imperial College London	150,559	79,741	78,918	78387.60	21	20	19	19	1.89	1.91	1.92
University of Michigan – Ann Arbor	148,665	71,438	75,112	71054.99	22	22	21	23	2.08	1.98	2.09
Swiss Federal Institute of Technology – Zurich	147,359	62,484	69,734	62461.85	23	24	24	24	2.36	2.11	2.36
University of Minnesota – Twin Cities	143,375	67,795	72,973	71252.68	24	23	23	22	2.11	1.96	2.01
University of Wisconsin – Madison	140,151	60,689	62,976	59389.27	25	27	27	29	2.31	2.23	2.36
University of Pennsylvania	131,694	58,722	59,072	55983.17	26	31	30	32	2.24	2.23	2.35
Rutgers University – New Brunswick	127,851	60,846	62,075	60977.05	27	26	28	26	2.10	2.06	2.10
The University of Chicago	127,831	58,815	57,876	56744.54	28	30	31	30	2.17	2.21	2.25
State University of New York – Stony Brook	127,447	55,555	57,800	56096.09	29	33	32	31	2.29	2.20	2.27
The Ohio State University – Columbus	121,324	42,078	45,112	42078.99	30	51	45	48	2.88	2.69	2.88

[a] The different graying levels of the background indicate the degrees of rank position changes (<15, 16–30, 30–60, >60).
[b] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

Table 5
Citation counts, university ranks, and counting inflation by different counting methods: the top 136–165 universities.

Institution	1989–2008 citation count by different counting method				Rank by citation count[a]				Ratio of counting inflation[b]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
University of Bristol	49,469	21,566	22,034	20376.47	136	133	137	140	2.29	2.25	2.43
Virginia Polytechnic Institute and State University	49,458	16,279	16,886	16898.52	137	185	182	174	3.04	2.93	2.93
University Louis Pasteur (Strasbourg I)	48,912	17,551	16,004	17025.14	138	170	191	173	2.79	3.06	2.87
University of California - Riverside	48,293	16,938	17,222	15568.37	139	174	178	190	2.85	2.80	3.10
Universite Claude Bernard Lyon 1	47,989	17,145	16,321	16542.80	140	172	187	179	2.80	2.94	2.90
International School for Advanced Studies	47,485	21,348	21,969	18821.14	141	139	139	162	2.22	2.16	2.52
University of Birmingham	47,119	14,733	14,429	11696.02	142	203	209	229	3.20	3.27	4.03
Katholieke Universiteit Leuven	46,163	24,535	25,335	24512.47	143	110	109	106	1.88	1.82	1.88
Universite de Montreal	46,051	24,213	18,580	19720.73	144	115	162	149	1.90	2.48	2.34
University of Rome Tor Vergata	45,897	15,699	17,451	15174.08	145	194	173	193	2.92	2.63	3.02
Technische Universitat Darmstadt	45,870	23,242	22,066	21891.11	146	120	135	123	1.97	2.08	2.10
Scuola Normale Superiore di Pisa	45,842	9309	9362	9176.98	147	246	243	245	4.92	4.90	5.00
University of Sussex	45,689	19,114	22,841	19704.75	148	160	125	150	2.39	2.00	2.32
Freie Universitat Berlin	45,571	28,101	27,823	27198.70	149	92	93	93	1.62	1.64	1.68
University of Cologne	45,234	25,077	25,861	23774.16	150	106	108	112	1.80	1.75	1.90
Northeastern University	45,026	18,514	18,310	19079.93	151	165	165	157	2.43	2.46	2.36
University of Innsbruck	44,900	20,034	22,546	19244.16	152	153	129	153	2.24	1.99	2.33
University of Alberta	44,796	16,859	18,168	16855.47	153	176	168	176	2.66	2.47	2.66
University of Genoa	44,673	7606	8810	8504.12	154	257	249	253	5.87	5.07	5.25
University of Hawaii–Manoa	44,630	6784	7941	7870.08	155	267	256	255	6.58	5.62	5.67
University of London – Queen Mary College	44,396	15,504	17,257	16459.95	156	197	177	182	2.86	2.57	2.70
Peking University	44,312	22,001	23,180	21757.40	157	125	124	126	2.01	1.91	2.04
Vanderbilt University	44,242	15,662	14,364	12727.43	158	195	210	221	2.82	3.08	3.48
Helsinki University of Technology	43,808	24,366	26,607	23406.63	159	114	101	115	1.80	1.65	1.87
Korea Advanced Institute of Science and Technology	43,796	25,904	26,271	25080.95	160	101	105	104	1.69	1.67	1.75
University of Basel	43,690	16,075	17,348	17959.21	161	187	175	166	2.72	2.52	2.43
Utrecht University	43,671	22,472	24,034	22619.23	162	122	118	116	1.94	1.82	1.93
University of Montpellier 2	43,536	21,390	23,326	22038.75	163	137	121	122	2.04	1.87	1.98
Jagiellonian University	43,501	13,572	12,460	14391.93	164	214	225	205	3.21	3.49	3.02
Leiden University	43,490	23,749	26,557	25352.31	165	118	102	103	1.83	1.64	1.72

[a] The different graying levels of the background indicate the degrees of rank position changes (<15, 16–30, 30–60, >60).
[b] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

Table 6
Citation counts, university ranks, and counting inflation by different counting methods: the top 270–299 universities.

Institution	1989–2008 citation count by different counting method				Rank by citation count[a]				Counting inflation ratio[b]		
	W	SF	SC	F	W	SF	SC	F	W/SF	W/SC	W/F
University of Granada	19,458	7089	7258	7500.51	270	261	260	259	2.74	2.68	2.59
The University of Adelaide	19,003	11,021	9352	10308.61	271	238	244	236	1.72	2.03	1.84
Shanghai Jiao Tong University	18,763	11,314	11,246	10091.00	272	236	235	238	1.66	1.67	1.86
George Mason University	18,341	2742	3695	3839.88	273	289	284	283	6.69	4.96	4.78
University of Victoria	17,804	3457	3456	4151.24	274	285	286	282	5.15	5.15	4.29
New Mexico State University	17,170	4363	4454	4507.56	275	282	281	281	3.94	3.85	3.81
University of Budapest	16,975	6955	6795	7652.85	276	263	264	256	2.44	2.50	2.22
National Cheng Kung University	16,926	11,475	12,174	10282.93	277	234	229	237	1.48	1.39	1.65
University of Liege	16,500	8408	8525	8631.74	278	251	253	251	1.96	1.94	1.91
Drexel University	16,318	6840	6044	6434.70	279	265	271	268	2.39	2.70	2.54
University of Crete	15,945	4763	4811	6126.76	280	278	278	271	3.35	3.31	2.60
Shandong University	15,533	9124	9643	9309.25	281	247	241	244	1.70	1.61	1.67
University of Bergen	15,142	3559	3692	3254.55	282	284	285	288	4.25	4.10	4.65
University of Ferrara	15,092	2863	2910	3203.27	283	288	290	289	5.27	5.19	4.71
Colorado State University	14,273	8742	9317	8349.61	284	249	245	254	1.63	1.53	1.71
Hanyang University	11,790	7343	7481	6931.74	285	259	257	264	1.61	1.58	1.70
Jilin University	11,399	6827	6917	7061.31	286	266	262	262	1.67	1.65	1.61
Nankai University	10,998	5564	5473	5613.23	287	274	274	272	1.98	2.01	1.96
Cardiff University	8879	4531	4380	4519.50	288	281	282	280	1.96	2.03	1.96
Monash University	8431	6014	6070	5452.19	289	271	270	273	1.40	1.39	1.55
University of Porto	8278	4795	4846	3663.65	290	277	277	286	1.73	1.71	2.26
The University of Mississippi	7669	2664	2901	2408.76	291	290	291	294	2.88	2.64	3.18
University of Leicester	6369	2546	3021	2933.32	292	292	289	291	2.50	2.11	2.17
Harbin Institute of Technology	5981	3792	3953	3733.54	293	283	283	285	1.58	1.51	1.60
Rochester Institute of Technology	4871	2516	2646	2698.34	294	293	292	292	1.94	1.84	1.81
The Catholic University of America	4456	1182	1036	1253.54	295	296	296	296	3.77	4.30	3.55
Pontificia Universidad Catolica de Chile	4298	2383	2558	2396.57	296	295	293	295	1.80	1.68	1.79
University of Hertfordshire	1825	850	763	956.39	297	297	297	297	2.15	2.39	1.91
University of Wyoming	1629	643	546	647.29	298	298	298	298	2.53	2.98	2.52
Liverpool John Moores University	899	595	542	563.53	299	299	299	299	1.51	1.66	1.60

[a] The different graying levels of the background indicate the degrees of rank position changes (<15, 16–30, 30–60, >60).
[b] The different graying levels of the background indicate the ranges of counting inflation ratio (<1.75, 1.75–2, 2–2.5, 2.51–3, >3).

Table 7
Spearman correlation analysis and comparative analysis of the rankings resulted from the four counting methods.

Counting method	1–300			1–100			101–200			201–300		
	W	SF	SC	W	SF	SC	W	SF	SC	W	SF	SC
Paper counts-based rankings												
SF	.944***	–	–	.910***	–	–	.428***	–	–	.849***	–	–
SC	.945***	.999***	–	.912***	**.996**	–	.419***	.990***	–	.853***	.995***	–
F	.947***	.997***	.996***	.916***	.996***	.993***	.442***	.981***	.968***	.857***	.994***	.992***

	1–50			51–100			101–150		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.933***	–	–	.584***	–	–	.146***	–	–
SC	.932***	**.996**	–	.595***	.979*	–	.143***	.987*	–
F	.938***	.994***	.990***	.589***	.986***	.971***	.157***	.979**	.964**

	151–200			201–250			251–300		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.533***	–	–	.540***	–	–	.798***	–	–
SC	.526***	.985**	–	.542***	.986**	–	.799***	.996*	–
F	.515***	.970***	.957***	.548***	.976**	.970***	.793***	.995***	.990**

	1–30			136–165			270–300		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.902***	–	–	.006***	–	–	.831***	–	–
SC	.887***	**.985**	–	−.019***	**.948**	–	.817***	.995*	–
F	.914***	.995***	.984***	−.042***	.973***	.916***	.831***	**.994**	.994**

Citation counts-based rankings	1–300			1–100			101–200			201–300		
	W	SF	SC	W	SF	SC	W	SF	SC	W	SF	SC
SF	.944***	–	–	.910***	–	–	.428***	–	–	.849***	–	–
SC	.945***	.999***	–	.916***	.996**	–	.419***	.990**	–	.853***	**.995**	–
F	.947***	.997***	.996***	.916***	.996***	.993***	.442***	.981*	.968***	.857***	.994**	.992**

	1–50			51–100			101–150		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.950***	–	–	.516***	–	–	.172***	–	–
SC	.948***	.981*	–	.472***	**.968**	–	.195***	**.961**	–
F	.945***	.989**	.988***	.561***	.958*	.943**	.234***	.974*	.962*

	151–200			201–250			251–300		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.110***	–	–	.459*	–	–	.720***	–	–
SC	.155***	.962**	–	.421*	**.970**	–	.690***	**.993**	–
F	.187***	**.975**	.963***	.458*	.973**	.952**	.725***	**.984**	**.983**

	1–30			136–165			270–300		
	W	SF	SC	W	SF	SC	W	SF	SC
SF	.950***	–	–	−.030***	–	–	.699***	–	–
SC	.964***	**.983**	–	−.234***	**.923**	–	.693***	**.992**	–
F	.964***	.973**	.989***	−.188***	**.961**	.960***	.770***	**.975**	**.975**

Note. The numbers in the tables are the Spearman coefficient values ($p < 0.01$). The values in bold are not significant.
* Significantly different at the $p < 0.05$ level.
** Significantly different at the $p < 0.01$ level.
*** Significantly different at the $p < 0.001$ level.

Table 8
Average and standard deviation of counting inflation ratio.

Range	Paper						Citation					
	W/SF		W/SC		W/F		W/SF		W/SC		W/F	
	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.
Top 1–100	1.87	0.29	1.86	0.27	1.92	0.29	2.43	0.63	2.39	0.63	2.46	0.59
Top 101–200	1.97	0.47	1.95	0.47	2.02	0.47	2.74	1.71	2.74	2.03	2.74	1.47
Top 201–299	2.07	0.54	2.05	0.53	2.11	0.53	2.57	1.38	2.57	1.41	2.56	1.26

inflation ratio among the adjacent peer institutions usually meant rank drop when whole counting is replaced by the other methods.

Table 8 shows the average inflation ratios and standard deviations in different zones of the top 300 list. The average inflation ratios for citation counts were all larger than paper counts by any counting method in each zone. This suggests that whole counting was prone to bias the assessment of institutional research impact even more than assessing research production.

5. Conclusion

This study revealed two major findings. First, although the rankings of the entire 300 universities generated from the four different counting methods were correlated, the choice of a particular counting method could seriously influence an institution's position in the ranking, especially for the middle-range universities. Second, counting methods impacted citation counts more than paper counts. This was evidenced in the larger rank changes and higher counting inflation observed in the samples. These suggest that, for the institutional-level research evaluation, straight counting and fractional counting are both better choices than whole counting. The previous research has demonstrated that straight counting and fractional counting are mathematically more logical than whole counting (Gauffriau et al., 2008) and empirically more consistent in reflecting country-level performance (Huang et al., 2011; Rinia, De Lange, & Moed, 1993). This study further confirmed the appropriateness of the two counting approaches for institutional-level evaluation. Furthermore, in today's academic cultures in which ranking results often influence national policies and resource allocation, the more precise counting methods like straight counting and fractional counting seem a better fit for those institutions that care about the accuracy and justifiability of evaluation methodology.

In regards to selecting straight counting or fractional counting for a fairer ranking result, some people may have felt uncomfortable if an evaluation program attributes credit only to the first author or the corresponding author's institution. Our analysis showed that the selection between the two approaches does not make much difference in terms of reflecting the global trend and the relative performance of a group of universities. The correlations of the rankings were all very high.

However, for each individual university that cares about its rank position among peers of similar performance level, the choice of counting methods can still make a significant difference. Only the very top universities and those located at the bottom may not be influenced by the selection of fractional or straight counting. In addition, choosing first author or corresponding author as the basis for straight counting can also affect universities' rank positions. Therefore, our conclusion based on the examination is that straight counting and fractional counting are better than whole counting in delivering a more consistent and less inflated representation of university performance. But the selection of a particular counting method inevitably benefits certain institutions and underrepresents the others. Universities located at the middle range were influenced most by the method choice. But we are not able to say which method better service the purpose of university ranking at this stage. For example, why straight counting based on the first author or corresponding author' institution can produce such significant difference is currently unclear. Future research may further explore various calculation methods for fractional counting and knowledge production relationships between the first, corresponding, and other supporting authors and may possibly develop proportional weighting techniques to better accredit each authoring institution.

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