Different Outcomes of Different Counting Methods for Publications and Citations[1]

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Abstract
For all rankings of countries research output based on number of publications, citations or most cited publications compared with population, GDP, R&D expenses and other national characteristics the counting method is decisive. Using data freely available the difference between numbers of publications based on Total Counting and Fractional Counting has been quantified. Reduction in numbers of publications going from Total to Fractional Counting ranges from 10 to 45 per cent for different countries. Rankings based on numbers of citations or highly cited papers most likely are even more dependent on the counting method used. Counting methods are in many cases not precisely described or discussed.

Introduction

Numbers of publications, citations and highly cited papers are often used as science indicators. This use is depending on ascribing credit for publications to countries, institutions or individuals. The problems and reservations due to different counting methods are well known (Anderson *et al,* 1988, Nederhof and Moed, 1993, Egghe, Rousseau & Van Hoydoonk, 2000). Nevertheless in many rankings these problems are overlooked or neglected. It is important to quantify the difference between different counting methods. We have as a first approach only considered ranking of nations and compared Total Counting, full credit for a publication to a country when at least one of the authors is from this country, and Fractional Counting, a country receives a fraction of full credit for a publication equal to the fraction of authors to the publication coming from this country.

Examples of rankings with great impact in scientometrics and research policy

A report in *Science* in 1997 (May, 1997) is depending on Total Counting. The question of counting method is addressed in a footnote: "A survey of different accounting methods (Bourke & Butler, 1994) suggests that these various approaches have relatively little effect on conclusions". The EU reports on Science & Technology Indicators are depending on Total Counting. The last edition (European Commission, 2003) contains the following statement: "There is no fair method to determine how much money, effort, equipment and expertise each researcher, institute or country has contributed to a paper and the underlying research effort.

Dividing up a paper between the participating units is therefore to some extent arbitrary. The basic assumption is that each author, main institution and country listed in the affiliated addresses has made a non-negligible contribution. Each paper is therefore assigned in full to all unique authors, institutions and countries listed in the address heading." OECD in its research statistics from 1999 (OECD, 1999) used Total Counting but subsequently in 2001 (OECD, 2001, 2003) changed to Fractional Counting without any comments on the change.

National Science Foundation (NSF), USA, in its most recent publication (National Science Foundation, 2004) is using Fractional Counting. In two rankings of universities worldwidefrom 2004 (Institute of Higher Education at Shanghai Jiao Tong University, 2004, & The Times Higher Education Supplement, 2004) the number of publications is used as one of the ranking criteria. Probably Total Counting was used, but in both rankings information about counting methods is given

[1] This work was supported by a grant from the Carlsberg Foundation.

Proceedings of ISSI 2005, pages 242–246.
Edited by P. Ingwersen and B. Larsen.

in references to sources not freely available. A report in *Nature* in 2004 (King, 2004) is depending on Total Counting. Counting methods are not discussed.

A quantitative comparison of Total and Fractional Counting

NSF provides numbers of publications by Total and Fractional Counting and numbers of internationally co-authored publications for individual countries for 2001 (and 1994), (National Science Foundation, 2004). Population numbers have been used to calculate publications per mill. inhabitants from the NSF-data. Table 1 shows data for national publication activity for 2001 in publications per mill. inhabitants according to both Total and Fractional Counting and for rankings based on these figures.

The number of internationally co-authored publications divided by the total number of publications in Total Counting gives the share of internationally co-authored publications. The difference between numbers from Total and Fractional Counting divided by the number of internationally co-authored publications is the fraction of authors to internationally co-authored publications originating from other countries than the country in question. This is the "loss" per internationally co-authored publication when going from Total to Fractional Counting, see table 2.

The use of Total and Fractional Counting

We have studied the information given in reports from EU, NSF, OECD and ten journals, all covered by Thomson ISI data bases, and containing the majority of papers about bibliometrics, scientometrics and informetrics in the past five years. Our conclusion is that information given and discussion about counting methods are often limited in the literature.

Discussion

If the change from Total to Fractional Counting should have no importance for national rankings, this would imply that all countries have the same fraction of internationally co-authored publications and were contributing to the co-authored publications with the same fraction of authors. Table 1, however, shows a range from 10 per cent (Japan) to 45 per cent (Iceland) in the reduction in number of publications per mill. inhabitants in going from Total to Fractional Counting. Table 2 shows a range from 0.197 (Japan) to 0.693 (Iceland) in the ratio of internationally co-authored publications to total publications.

NSF also provides complete data for 1994 and therefore NSF data can be used to study the development of international co-authorship. For all countries international co-authorship is increasing. Therefore the question of counting method is increasingly important.

The data discussed here are for total numbers of publications from all scientific and engineering fields. There is however big differences in the number of authors per publication and in the degree of international collaboration between fields. It will also be of interest to study the difference in ranking of institutions depending on counting methods.

The problems connected with counting methods would only be identical for number of publications, citations and highly cited publications if international and co-authored publications on average are cited just as much as national and single-authored publications. However international and multi-authored publications receive more references than national and single-authored publications (Glänzel, 2001). Therefore the differences between results obtained through Total and Fractional Counting will be greater when citations are studied.

Table 1. The difference between Total and Fractional Counting

	Population in mill. 2001	S&E Articles, Total Counting, 2001.	Publications per mill. inhabitants, Total Counting, 2001 (**ranking**).	S&E Articles, Fractional Counting, 2001.	Publications per mill. inhabitants, Fractional Counting, 2001 (**ranking**).	Reduction by going from Total to Fractional Counting. Per cent
Australia	19.3	18,589	963 **(11)**	14,788	766 **(8)**	20
Austria	8.1	6,476	800 **(14)**	4,526	559 **(16)**	30
Belgium	10.3	8,818	856 **(13)**	5,984	581 **(15)**	32
Canada	31.0	28,846	931 **(12)**	22,626	730 **(10)**	22
Czech Republic	10.3	3,753	364 **(25)**	2,622	254 **(24)**	30
Denmark	5.3	7,136	1,346 **(4)**	4,988	941 **(5)**	30
Finland	5.2	6,747	1,298 **(5)**	5,098	980 **(4)**	24
France	59.5	41,397	696 **(18)**	31,317	526 **(18)**	24
Germany	82.0	57,231	698 **(17)**	43,623	532 **(17)**	24
Greece	10.6	4,371	412 **(23)**	3,329	314 **(23)**	24
Hungary	9.9	3,624	366 **(24)**	2,479	250 **(25)**	32
Iceland	0.29	316	1,090 **(6)**	174	600 **(14)**	45
Ireland	3.8	2,280	600 **(19)**	1,665	438 **(20)**	27
Israel	6.2	8,502	1,371 **(3)**	6,487	1,046 **(3)**	24
Italy	57.5	28,384	494 **(22)**	22,313	388 **(22)**	21
Japan	127.3	64,073	503 **(20)**	57,420	451 **(19)**	10
Mexico	100.4	4,393	44 **(28)**	3,209	32 **(28)**	27
Netherlands	15.9	17,134	1,078 **(7)**	12,602	793 **(7)**	26
New Zealand	3.8	3,716	978 **(10)**	2,903	764 **(9)**	22
Norway	4.5	4,503	1,001 **(9)**	3,252	723 **(11)**	28
Poland	38.6	7,901	205 **(27)**	5,686	147 **(27)**	28
Portugal	10.0	3,056	306 **(26)**	2,142	214 **(26)**	30
Singapore	4.1	3,212	783 **(16)**	2,603	635 **(13)**	19
Spain	39.9	19,809	496 **(21)**	15,570	390 **(21)**	21
Sweden	8.8	14,096	1,602 **(2)**	10,314	1,172 **(1)**	27
Switzerland	7.2	12,067	1,676 **(1)**	8,107	1,126 **(2)**	33
United Kingdom	59.5	60,438	1,016 **(8)**	47,660	801 **(6)**	21
USA	285.9	228,015	798 **(15)**	200,870	703 **(12)**	12

Population numbers from www.unpfa.org/swp/2001, Iceland from www.hagstofa.is

Table 2. International co-authorship

	Internationally co-authored articles, 2001	Share of internationally co-authored articles, 2001	"Loss" per internationally co-authored article in going from Total to Fractional Counting, 2001
Australia	6,751	0.363	0.56
Austria	3,291	0.508	0.59
Belgium	4,724	0.536	0.60
Canada	11,070	0.384	0.56
Czech Republic	1,936	0.516	0.58
Denmark	3,609	0.506	0.60
Finland	2,892	0.429	0.57
France	17,918	0.433	0.56
Germany	23,887	0.417	0.57
Greece	1,812	0.415	0.58
Hungary	1,987	0.548	0.58
Iceland	219	0.693	0.65
Ireland	1,065	0.467	0.58
Israel	3,561	0.419	0.57
Italy	11,269	0.397	0.54
Japan	12,622	0.197	0.53
Mexico	2,066	0.470	0.57
Netherlands	7,692	0.449	0.59
New Zealand	1,435	0.386	0.57
Norway	2,112	0.469	0.59
Poland	3,798	0.481	0.58
Portugal	1,619	0.530	0.56
Singapore	1,107	0.345	0.55
Spain	7,508	0.379	0.56
Sweden	6,524	0.463	0.58
Switzerland	6,455	0.535	0.61
United Kingdom	22,328	0.369	0.57
USA	52,862	0.232	0.51

Conclusion

The results show that rankings based on publications per mill. inhabitants are influenced strongly by the use of Total or Fractional Counting. The implications reach however much farther. Counting methods are decisive for:

1. Rankings based on comparisons of number of publications with population size, GDP, R&D expenses, public R&D expenses and other national characteristics
2. Rankings based on calculations of a country's share of the world total or a regions total number of publications.
3. Rankings based on comparisons of number of citations with population size, GDP, R&D expenses, public R&D expenses and other national characteristics.
4. Rankings based on calculations of a country's share of the world total or a regions total number of citations.
5. Rankings based on comparisons of number of highly cited publications with population size, GDP, R&D expenses, public R&D expenses and other national characteristics.
6. Rankings based on calculations of a country's share of the world total or a regions total number of highly cited publications.

It is necessary in publication and citation studies clearly to describe the counting methods used. The problem must be addressed when studying and using older publications.

There is an urgent need for quantitative studies of differences between counting methods between different scientific fields and on the influence of counting methods on rankings based on citations.

Part of the results presented here will also occur in a paper in *Scientometrics* (Gauffriau and Larsen, 2005).

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