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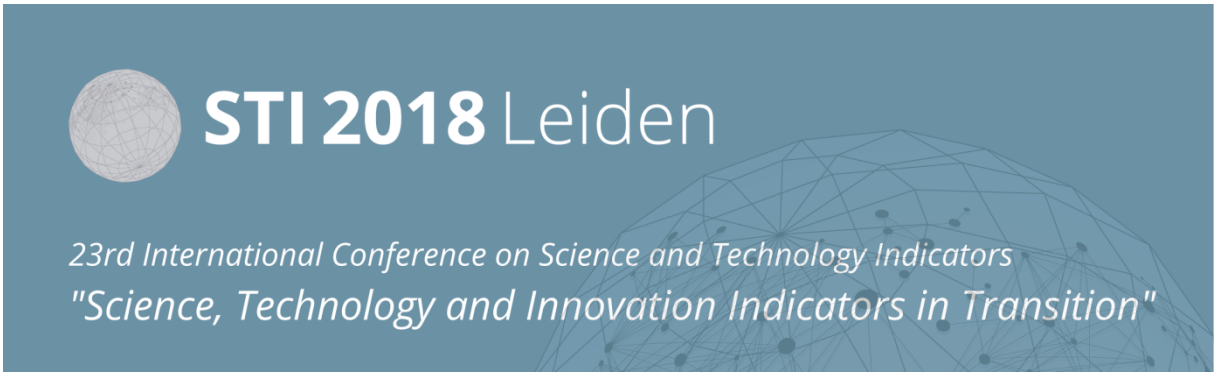

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A New h³-index for Academic Journals

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Introduction

Different metrics have been developed to evaluate journal impact, a journal's influence, and indirectly journal quality. Among these we mention the Journal Impact Factor (JIF), the SCR index, and several h-type indexes.

Just as authors, also journals have an h-index, and its corresponding h-core (Rousseau, 2006) containing the h most cited articles (Braun, Glänzel & Schubert, 2006; Harzing and van der Wal, 2009). The h-index of highly cited journals fluctuates, depending on the field, from over 100 to 250 and even 1000 for Science or Nature (based on data on the Web of Science or comparable in Scopus, but with values up to the double when based on Google Scholar).

The h-index

Since the introduction by Hirsch of the h-index (Hirsch, 2005) the number of academic publications has substantially increased, and so has the number of journals selected by the main databases. This trend has been followed by a tremendous increase in the number of academic articles. Consequently, the number of citations has increased exponentially. This has in turn led to a rapid increase of journals' h-index and other h-type indexes.

The h-index of academic journals has thus also increased rapidly. As an illustration of the differences in publication and citation distribution of different scientific outlets, tables 1 to 3 present data extracted from the Web of Science about three academic journals with a total different profile. First, the leading bibliometrics journal *Scientometrics*, with a few hundred of articles per year; then a very selective general management journal, the *Strategic Management Journal* (SMJ), with approximately 50 articles per year, but with a high amount of highly cited articles in the management field, and a third outlet, *Nature*, one of the leading scientific journals that cover all major disciplines with a high publication frequency. Since its establishment *Scientometrics* has published about 5000 articles, *SMJ* only 2700 and *Nature*, the eldest journal among these three nearly 200.000 articles.

Table 1 presents data for the journal *Scientometrics*. In the first part of this table, one finds the number of articles in the journal, the total number of received citations, the average of citations per paper; further, the following indexes: the g-index, the h-index and the h² and h³indexes (see infra). The g-index is defined as "the unique largest number such that the top g articles received together at least g² citations" (Egghe, 2006: 131). The complementary h²-or Kosmulski-index gives the largest number of h1 articles such that h1 articles received each at least h1² citations (Kosmulski, 2006). The h³-index will be presented in the upcoming section

of the paper (Rousseau, 2006). For each of these h-indexes, a corresponding h-core (or g or h^2-core) groups the h (or g or h^2) most cited articles of the set of articles. The second part of the table shows the number of citations of respectively, the most-cited paper, the 10th mostcited paper, the 100th most cited paper, the amount of citations corresponding to the journal's g-, h-, h^2- and h^3-core; the amount of citations for the 10%, 1% and 0.1% percentiles in the citation distribution.

Table 1. Data and indexes related to the journal *Scientometrics* (retrieved on 9th July 2018)

Period	n	tot cit	avg/n	g	h	h^2	h^3
until 1990	626	1992	3.2	23	17	5	3
until 1995	1032	3750	3.6	31	23	6	3
until 2000	1530	6668	4.4	39	29	7	3
until 2005	2041	11818	5.8	49	36	7	4
until 2010	2886	25695	8.9	80	59	10	5
until 2013	3641	42029	11.5	107	72	13	5
until 2015	4369	56503	12.9	126	85	14	6
all years	5285	78187	14.8	149	96	16	6

n citations	max	10	100	g	h	h^2	h^3	10%	1%	0.10%
until 1990	41	24	7	15	17	35	35	10	33	41
until 1995	63	33	11	21	23	44	49	11	33	63
until 2000	113	47	15	25	29	51	62	11	40	73
until 2005	134	60	22	32	36	68	83	14	49	88
until 2010	184	117	40	48	59	117	139	22	84	159
until 2013	408	187	60	58	72	170	202	27	111	224
until 2015	562	233	75	65	85	211	260	29	128	274
all years	730	286	92	76	95	256	320	33	144	324

The table shows the increase of the total citations from around 2000 in 1990 to more than 78,000 by 2018. In that same time period, the number of citations of the most cited article rose from 41 to 730, while the 10th most cited article increased from 24 to 286 and the 100th most cited article rose from 7 to 92. The h-index rose from 17 in 1990 to 59 in 2010 to 95 in 2018.

The same data calculated for one of the leading management journals, the *Strategic Management Journal* (SMJ), is presented in table 2.

Table 2. Data and indexes about Strategic *Management Journal* (SMJ) (retrieved on 7th April 2018)

Period	n	tot cit	avg/n	g	h	h^2	h^3
until 1990	458	2505	5.5	31	24	6	3
until 2000	1115	17920	16.1	102	69	12	5
until 2010	1828	99434	54.4	291	173	23	10
all years	2701	337594	125.0	489	271	33	13

n citations	max	10	100	g	h	h²	h³	10%	1%	0.10%
until 1990	75	31	8	20	24	38	53	15	46	75
until 2000	449	166	54	53	69	159	213	51	165	449
until 2010	3292	1035	239	115	173	575	1035	167	623	3114
all years	8305	2211	602	169	271	1121	1768	275	1244	5009

Table 2 for the SMJ-journal shows an even higher increase from 75 to 8167 citations for the most cited article of that journal, and an h-index that rose from 24 to 271.
Table 3 presents the data for *Nature*, the eldest and most productive journal. This table shows also an exponential increase in the number of publications and the number of citations. The hindex of *Nature* has increased from 42 in 1960 to 644 in 2000 and reached 1229 by mid-2018.

Table 3. Data and indexes about the journal *Nature* (retrieved on 19th June 2018)

Period	n	g	h	h²	h³
until 1960	16090	58	41	8	4
until 1970	54968	166	125	16	7
until 1980	83055	346	219	26	10
until 1990	117442	676	372	34	12
until 2000	149756	1075	644	46	15
until 2010	176383	1517	932	55	18
all years	196301	1969	1229	69	20

n citations	max	2	10	100	h	h²	h³	1%	0.1%
until 1960	199	161	78	27	41	82	103	22	61
until 1970	1028	634	405	134	125	290	452	58	171
until 1980	9485	2952	938	325	219	669	1001	153	358
until 1990	80148	6891	2057	754	372	1228	1977	230	692
until 2000	171360	9974	3976	1548	639	2126	3628	408	1323
until 2010	221292	16712	7928	2573	925	3040	5934	569	2091
all years	243700	29704	11026	3932	1235	4789	8841	957	2974

As the most cited article in Nature is a outlier, around 8 times more than the next, I also include the second highest cited article with the 10th and 100th article.

The h-percentile
The h-percentile (and, by analogy, for other h-related indexes as well as the g-percentiles) of a dataset is the percentile corresponding with the place of h (respectively g) in the citation distribution table, so, h or g divided by the total number of articles in the dataset at study (Fassin, 2018). The h-percentile of the articles in the journal's h-core, also changes over the years. As table 4 illustrates, the h-core of *Scientometrics* remained at around 2% from 2000 to 2018.

Table 4. The h-percentiles of *Scientometrics*

Period	n	g	h	h^2	h^3	g	h	h^2	h^3
until 1990	626	23	17	5	3	3.67%	2.72%	0.80%	0.48%
until 1995	1032	31	23	6	3	3.00%	2.23%	0.58%	0.29%
until 2000	1530	39	29	7	3	2.55%	1.90%	0.46%	0.20%
until 2005	2041	49	36	7	4	2.40%	1.76%	0.34%	0.20%
until 2010	2886	80	59	10	5	2.77%	2.04%	0.35%	0.17%
until 2013	3641	107	72	13	5	2.94%	1.98%	0.36%	0.14%
until 2015	4369	126	85	14	6	2.88%	1.95%	0.32%	0.14%
all years	5285	149	96	16	6	2.82%	1.82%	0.30%	0.11%

The h-percentile of *SMJ* however, doubled from 5 to 10% from 1990 to 2018.

Table 5. The h-percentiles of *Strategic Management Journal* (SMJ)

Period	n	g	h	h^2	h^3	g	h	h^2	h^3
until 1990	458	31	24	6	3	6.8%	5.24%	1.31%	0.66%
until 2000	1115	102	69	12	5	9.1%	6.19%	1.08%	0.45%
until 2010	1828	291	173	23	10	15.9%	9.46%	1.26%	0.55%
all years	2701	489	271	33	13	18.1%	10.03%	1.22%	0.48%

The h-percentiles of *Nature* also doubled from 1990 to 2018, but from 0.32 to 0.63%, while the h^3-percentile stabilized around 0.01%.

Table 6. The h-percentiles of *Nature*

Period	n	g	h	h^2	h^3	g	h	h^2	h^3
until 1960	16090	58	41	8	4	0.36%	0.25%	0.050%	0.025%
until 1970	54968	166	125	16	7	0.30%	0.23%	0.029%	0.013%
until 1980	83055	346	219	26	10	0.42%	0.26%	0.031%	0.012%
until 1990	117442	676	372	34	12	0.58%	0.32%	0.029%	0.010%
until 2000	149756	1075	644	46	15	0.72%	0.43%	0.031%	0.010%
until 2010	176383	1517	932	55	18	0.86%	0.53%	0.031%	0.010%
all years	196301	1969	1229	69	20	1.00%	0.63%	0.035%	0.010%

The huge differences in the h-percentile point to the variety of strategies of the different journals: general versus focused; highly selective versus broader scope.

The h^2-index

A more selective h-type index has been proposed by Kosmulski: the h^2-index (Kosmulski, 2006). This Kosmulski-index has been applied to authors, but not frequently for journals. Just as the h-index, the h^2-index increases over the years, with new citations, but to a lower extend than the h-index. For the journal *Scientometrics*, the h^2-index and the corresponding h^2-core increased from 5 in 1990 to 16 in 2018; from 6 to 33 in *SMJ* and from 34 to 68 in *Nature*.

The h^2-percentile, corresponding to the journal's h^2-core, decreased for *Scientometrics* from 0.8 to 0.3%, and stabilized for *SMJ* around 1.25 % and around 0.030 to 0.035 % for *Nature*. Due to the increase of number of publications, and thus also increase of citations, this increase

of the h and h²-indexes is even much higher than in the past. This temporal-related phenomenon reduces differentiation and selectivity of the h and h²-index.
There are great differences between different journals, depending on the field, the size and publication frequency of journals and also on the citation patterns in the field.
Table 7 shows the number of articles, the h and h²-indexes and the corresponding h-cores of a number of well-known journals such as *Science*, *Nature* and *PLOS One* with a very high number of articles and citations. Besides these journals, as an illustration, the same indexes are presented for a number of more specialized and focused publications in different areas of medicine (the *Lancet* and the *New England Journal of Medicine* - NEJ Medicine), bibliometrics (the *Journal of the American Society for Information Science and Technology* JASIST and *Scientometrics*), physics (*Physics Letters A*) plant sciences (*Cell* and the *European Molecular Biology Organization Journal* EMBO) and management (the *Academy of Management Review*, the *Harvard Business Review* HBR, the *Journal of Business Venturing* JBV, the *Journal of Business Ethics* JBE and *Business Ethics A European Review BEER*). This table illustrates the variety of citation patterns in varied fields.

Table 7. The h-indexes and h-percentiles of selected publications

Journal	n	h	h^2	h^3	% h	% h^2	% h^3
Science	133,507	1213	68	19	0.91%	0.051%	0.014%
Nature	196,613	1233	68	20	0.63%	0.035%	0.010%
Plos One	197,901	238	23	9	0.12%	0.012%	0.005%
Lancet	175,717	713	48	15	0.41%	0.027%	0.009%
NEJ Medicine	96,480	972	60	17	1.01%	0.062%	0.018%
Physics Letters A	46,422	201	17	9	0.43%	0.037%	0.019%
Cell	20,228	871	56	17	4.31%	0.277%	0.084%
EMBO	18,129	439	33	12	2.42%	0.182%	0.066%
JASIST	2,544	81	13	6	3.18%	0.511%	0.236%
Scientometrics	5,255	95	16	6	1.81%	0.304%	0.114%
AMR	2,304	284	34	13	12.33%	1.476%	0.564%
HBR	14,419	126	26	10	0.87%	0.180%	0.069%
JBV	1,090	144	20	8	13.21%	1.835%	0.734%
JBE	7,155	128	10	6	1.79%	0.140%	0.084%
BEER	323	26	7	4	8.05%	2.167%	1.238%

The h-indexes of the major journals in bibliometrics approach the 100; in management the hindex varies between 150 in entrepreneurship to 300 in general management. The field of medicine has much higher values (around 1000). *Science* and *Nature* obtain an h-index above 1200. The h²-indexes range from 7 to 34 in management, 16 in bibliometrics, 60 in medicine and *Nature* and *Science* culminate with an h²-index of 68.
The h-percentile remains under 1% in the large journals with a high number of articles; the hpercentile of bibliometrics journals amounts around 2 to 4, while in management journals it ranges between 1 and 13%. The h²-percentiles are more selective and more stable: 0.05 % in top journals in medicine and *Science*; 1.5 % in the *Academy of Management Review*.
With the increase of articles and citations, the selectivity of the h-index and h²-index has diminished, and benchmarking gets more difficult. An h-index of 5 or 7 makes a difference,

and certainly does an h²-index of 7 or 9. However, whether the h-index is 140 or 150, or the h²index 33 or 35, is not really informative.

The h³-index

In order to reduce the number of thresholds, and to increase differentiation between successive thresholds, I propose an even more severe criterion: the h³-index. It is defined as follows: the h^3 index of a journal J is equal to h if journal J has published h articles which each have received at least h^3 citations, while this statement is not true for h+1. So, a journal has an h³-index of 4 if the 4^{th} most cited paper has at least 4^3 or 64 citations, while the 5^{th} highest cited paper has less than 125 citations; it has an h³-index of 10 if it has 10 papers with more than 1000 citations, and not 11 papers with at least 1331 citations (see table 8). At present, end of June 2018, only a few journals achieve scores over 15 such as *Nature* with 20 and *Science* with 19.

Table 8. Thresholds for the h³-index

h^3	nr citations	h^3	nr citations	h^3	nr citations	h^3	nr citations
1	1	6	216	11	1331	16	4096
2	8	7	343	12	1728	17	4913
3	27	8	512	13	2197	18	5832
4	64	9	729	14	2744	19	6859
5	125	10	1000	15	3375	20	8000

Tables 1 to 7 also present the h³-index for the different datasets. While the h³-index for journals rapidly increases to 4 or 5, the following threshold takes longer to surpass. *Scientometrics* rose from an h³ of 3 till 2000 to 4 around 2005, to 5 around 2010, and to 6 around 2015. The *Strategic Management Journal* moved from 5 in 2000 to 10 in 2010 and to 13 by 2018. *Nature* increased from 4 to 12 between 1960 and 1990, and moved up to 20 in 2018.

Selectivity of the h³-core and h³-percentile rapidly increases with an increasing h³-index. *Scientometrics*' h³-core decreased from 0.48 to 0.11% from 1990 till 2018; *SMJ*'s h³-core from 0.66 to 0.49%, while *Nature* stabilized around 0.010%.

The list of selected journals in table 7 shows that most journals have a h³-index between 6 and 15, with a limited number of journals that surpass the value 15, especially in highly cited domains as medicine and plant science, and the multidisciplinary top journals *Nature* and *Science*, that reach a h^3-index of 20 and 19. The range of average ratios between the highest and lowest h³-indexes of the main journals in a specific field reaches 2 or 3 and exceptionally 5, which allows comparative benchmarking.

Incremental increase in quantum steps

The incremental increase to raise the h²-index by 1 is much higher than for the h-index, and even more important to raise the h³-index by 1. To raise the level of the h-index from 10 to 11 demands on average 10% more citations, to raise the h²-index from 10 to 11 requires an average increase of 21% citations; to raise a h³-index of 10 to 11 needs 33% more citations. However, for a higher h-index this increment gradually decreases. Indeed, at a higher level, a raise of the h-index from 30 to 31 needs on average a marginal increase of 3%; a raise from 100 to 101, only 1%. To increase the h²-index from 30 to 31 requires 7% more citations. To increase the h³-index from 14 to 15 requires 25% more citations. The incremental increase in citations to bring the next quantum increase is thus much more important in percentage and

certainly in absolute figures for h^3-indexes than for the h^2- and h-indexes, especially at the level of the highest categories. A raise in h^3-index takes longer; the h^3-index is more stable than the h^2- and the more volatile h-index.

Correlation between h-indexes

A correlation analysis between the h- h^2 and h^3-indexes was performed for a selection of 50 important management journals selected from the leading journals in FT50, half of the 50 leading management journals used in the Financial Times Research rank, and half consisting in specialized journals in a few specific management sub-fields. Table 9 shows the data of the sample with the average, maximum and minimum number of articles of the 50 selected publications, and similar data for the total number of citations of those publications, their h, h^2 and h^3-index. The h-index varied from 18 to 299; the h^2-index from 6 to 35 and the h^3-index from 2 to 13, while the average indexes were respectively 139, 19 and 8. The correlation between h and h^3 was 0.952; it was 0.982 between h^2 and h^3, and 0.976 between h and h^2. The statistical correlation between the h, h^2 and h^3-indexes shows that the h^3-index can to a certain extent be regarded as an equivalent index for h or h^2, but requiring a much shorter list of highly-cited publications.

Table 9. Data related to 50 management journals

	n	**tot cit**	**h-index**	**h^2**	**h^3**
avg	3012	128705	139	19	7.9
max	8567	488759	299	35	13
min	1332	4080	18	6	2

Table 10. Pearson correlation between 50 management journals

	h^3	**h^2**	**h-index**
h^3	1		
h^2	0.982	1.000	
h	0.952	0.976	1

The h^3-index for all datasets and fields

The h^3-index can also be calculated for other datasets, for examples for a complete scientific domain. Table 11 shows the h, h^2 and h^3 articles for the fields of science (in general), plant sciences, physics, management, business, entrepreneurship and bibliometrics (based on simple queries as ‘topic’ in the WoS). We notice similar discrepancies between different scientific domains. Similarly, as for the h-index, the h^3-index can also be calculated for individual scholars, for a department or for a university.

Table 11. The h-indexes and h-percentiles of selected scientific domains

Field	n (x1000)	h	h^2	h^3	% h	% h^2	% h^3
Science	1540	913	57	17	0.06%	0.004%	0.0011%
Plant science	286	495	38	*14*	0.17%	0.013%	0.0049%
Physics	476	693	52	16	0.15%	0.011%	0.0034%
Management	1979	818	57	17	0.04%	0.003%	0.0009%
Business	287	415	37	12	0.14%	0.013%	0.0042%
Management (Business)	167	476	38	14	0.29%	0.023%	0.0084%
Entrepreneurship	24.033	232	26	10	0.97%	0.108%	0.0416%
Bibliometrics	9.386	109	16	7	1.16%	0.170%	0.0746%

Conclusion

The proposed h^3-index offers a valuable alternative to existing journal impact factors and is very simple to calculate from databases. With its gradual exponential character, it better differentiates through the quantum step approach and is more selective than existing h and h^2indexes. The statistical correlations between the h-, h^2 and h^3-indexes show a certain equivalence. The advantage of the h^3-index is that it can be defined by a much smaller set of the top-cited highly-cited articles of the dataset. The h^3-index requires only the top 15 of the most cited articles (and exceptionally 20 as for *Nature*), compared to 50 to 70 for the h^2-index and 500 to 1200 for the h-index. The h^3-index allows benchmarking journals within scientific domains. A change in h^3-index has more meaning than a change in h-index. Moreover, thanks to its slow incremental increase, the h^3-index shows more stability. h^3-Indexes can be calculated for other datasets, e.g. of authors or institutions and offer similar advantages of higher selectivity.

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