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The *R*- and *AR*-indices: Complementing the *h*-index

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Based on the foundation laid by the *h*-index we introduce and study the *R*- and *AR*-indices. These new indices eliminate some of the disadvantages of the *h*-index, especially when they are used in combination with the *h*-index. The *R*-index measures the *h*-core's citation intensity, while *AR* goes one step further and takes the age of publications into account. This allows for an index that can actually increase and decrease over time. We propose the pair (*h*, *AR*) as a meaningful indicator for research evaluation. We further prove a relation characterizing the *h*-index in the power law model.

h-index, *A*-index, *R*-index, *AR*-index, *g*-index, performance evaluation, power law

1 The Hirsch index

The *h*-index, also known as the Hirsch index, was introduced by Hirsch[1] as an indicator for lifetime achievement. Considering a scientist's list of publications, ranked according to the number of citations received, the *h*-index is defined as the highest rank such that the first *h* publications received each at least *h* citations. It became soon clear that the *h*-index can not only be used for lifetime achievements, but also in the context of many—but not all—other source-item relationships[2,3]. Consequently, the Hirsch index has been calculated for journal citations[2,4], topics[5,6], library loans per category[7], and, pre-dating its actual introduction, even cycling[8]. In this paper we will, however, mainly use the terminology of publications and citations.

1.1 The Hirsch core

All publications ranked between rank 1 and rank *h* form the Hirsch core. If there are several publications with the same number of citations, then one may use two approaches to determine the Hirsch core. Either one includes all publications with *h* citations (hence the Hirsch core may contain more than *h* elements), or one introduces a secondary criterion for ranking. A good idea is ranking articles with the same number of citations in anti-chronological order so that more recent articles have a larger probability to belong to the Hirsch core than older ones. The Hirsch core can be considered as a group of high-performance publications, with respect to the scientist's career. Hence the term 'high-performance' should be understood in a relative sense.

1.2 Advantages and disadvantages of the *h*-index

We recall some advantages and disadvantages of the *h*-index that have been put forward in the literature[1,9].

Advantages

- It is a mathematically simple index.
- It encourages a large amount of high quality (at least highly visible) work.
- The *h*-index can be applied to any level of aggregation.
- It combines two types of activity (in the original setting this is citation impact and publications).

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•It is a robust indicator[10]. Increasing the number of publications alone does not have an immediate effect on this index.

•Single peaks (top publications) have hardly any influence on the *h*-index.

•In principle, any document type can be included.

•Publications that are hardly ever cited do not influence the *h*-index. In this way, the *h*-index discourages publishing unimportant work.

•It has been shown that the *h*-index is closely correlated to total publication output[1].

Disadvantages

•The *h*-index, in its original setting[1], puts newcomers at a disadvantage since both publication output and observed citation rates will be relatively low. In other words, it is based on long-term observations.

•The index allows scientists to rest on their laurels since the number of citations received may increase even if no new papers are published.

•The *h*-index is only useful for comparing the better scientists in a field. It does not discriminate among average scientists.

•This indicator can never decrease.

•The *h*-index is only weakly sensitive to the number of citations received. Indeed, when a scientist's *h*-index is equal to *h*, then this scientist's first *h* articles received at least *h* times *h*, i.e. h^2 citations. This lower bound is the only relation that logically exists between publications and citations, when the *h*-index is known.

The two previously mentioned disadvantages may be summarized by stating that the *h*-index lacks sensitivity to performance changes.

Moreover, the *h*-index suffers from the same problems as all simple indicators that use citations.

•Like most pure citation measures it is field-dependent, and may be influenced by self-citations.

•There is a problem finding reference standards.

•There exist many more versatile indicators[11].

•It is rather difficult to collect all data necessary for the determination of the *h*-index. Often a scientist's complete publication list is necessary in order to discriminate between scientists with the same name and initial. We refer to this problem as the precision problem.

It seems that in most applications colleagues have used only Web of Science data. Such a practice is not implied by the definition of the *h*-index, but when restricting data to WoS data this punishes colleagues who have highly cited articles in conference proceedings or journals, including web journals, not covered by the Web of Science (WoS).

Although (or because?) the *h*-index is a relatively simple indicator it immediately attracted a lot of attention from the scientific community[12−18].

1.3 Other *h*-type indices

In view of the advantages and disadvantages mentioned above it is no surprise that colleagues proposed some simple variations on the *h*-index idea[19,20], elaborated mathematical models[3,21,22] and proposed some new 'Hirsch-type' indices trying to overcome some of the disadvantages. Among these we mention Egghe's *g*-index[23,24], Kosmulski's $H^{(2)}$-index[25] and Jin's *A*-index[26].

For the *g*-index as well as for the $H^{(2)}$-index one draws the same list as for the *h*-index. The *g*-index, on the one hand, is defined as the highest rank such that the cumulative sum of the number of citations received is larger than or equal to the square of this rank. Clearly $h \leqslant g$. The $H^{(2)}$-index, on the other hand, is *k* if *k* is the highest rank such that the first *k* publications received each at least k^2 citations. The main advantage of this index is that it reduces the precision problem. We think however that this index is not sensitive enough[7] and will not consider it anymore in this article. The *g*-index clearly overcomes the problem that the *h*-index does not include an indicator for the internal changes of the Hirsch core. Yet, it requires drawing a longer list than necessary for the *h*-index, hence increasing the precision problem.

1.4 The *A*-index and the new *R*-index

Jin's *A*-index achieves the same goal as the *g*-index, namely correcting for the fact that the original *h*-index does not take the exact number of citations of articles included in the *h*-core into account. This index is simply defined as the average number of citations received by the publications included in the Hirsch core. The name of this index is derived from the fact that it is just an average (*A*). Mathematically, this is,

$$A = \frac{1}{h}\sum_{j=1}^{h} cit_j. \tag{1}$$

In formula (1) the numbers of citations (cit_j) are ranked in decreasing order. Note that, as long as the Hirsch core contains exactly *h* elements, the *A*-index is unambiguously defined. The *A*-index, moreover, uses the same data as the h-index so that the precision problem is exactly the same as for the original h-index, and is not increased as in the case of the g-index. Clearly $h \leqslant A$. Yet, the A-index suffers from another problem illustrated by the following fictitious case. Assume that scientist X_1 has published 20 articles, one cited 10 times and all other ones just once. Scientist X_2 has published 30 articles, one cited 10 times and all other ones exactly twice. Clearly, scientist X_2 is the better one. This is expressed by their h-indices which are 1 for X_1 and 2 for X_2. Yet their A-indices are 10 for X_1 and 6 for X_2. The better scientist is 'punished' for having a higher h-index, as the A-index involves a division by h. This is, however, only a small problem which can easily be solved by simply taking the sum, or, the square root of the sum. Taking the square root has the advantage of leading to indicator values which are not very high and of the same dimension as the A-index. As this new index is calculated using a (square) root we refer to it as the R-index.

As a mathematical formula the R-index is defined as

$$R = \sqrt{\sum_{j=1}^{h} cit_j}. \tag{2}$$

Clearly, $R=\sqrt{A.h}$. In general one may write $R(X,Y)$, where X denotes a particular scientist and Y the year for which the R-index has been calculated. As this is of no importance in our investigations we omit the symbols X and Y. It is clear that $h \leqslant R$ as each cit_j is at least equal to h. In the special case where each cit_j is exactly equal to h, $R = h$. This nice result is another advantage of using the square root of the sum, and not the sum itself.

1.5 Further relations between *h*, *A*, *R* and *g*

We have already observed that $h \leqslant g$, $h \leqslant A$ and that $R = \sqrt{A.h}$. Now we show one less obvious relation between A and g, and hence between h, A, R and g.

Proposition 1. The following inequalities always hold:

$$A \geqslant g \geqslant h. \tag{3}$$

Proof. The last inequality is already known. Now

$$A = \frac{\sum_{j=1}^{h} cit_j}{h} \geqslant \frac{\sum_{j=1}^{g} cit_j}{g}.$$

This inequality holds because the citations (cit_j) are ranked in decreasing order, hence the average number of citations of the first m articles is a decreasing function of m. As the g-index satisfies the relation

$$\sum_{j=1}^{g} cit_j \geqslant g^2 \quad \text{or} \quad \frac{\sum_{j=1}^{g} cit_j}{g} \geqslant g.$$

This proves the first inequality in line (3).

The following corollary, involving the four indices under study follows immediately.

Corollary.

$$R = \sqrt{A.h} \geqslant \sqrt{g.h} \geqslant h. \tag{4}$$

In practice the R-index is correlated to the h-index (see further) but, especially for individual scientists, does add another view on scientist's achievements.

1.6 Relations between *h*, *A*, *R* and *g* in the power law model

In this section we show how the four indices: h, A, R and g are related in the power law model. The power law model[27] assumes that the number of sources producing x items, e.g. authors' articles receiving citations, is given by the function F:

$$F: [1, +\infty[\rightarrow]0, C]: x \rightarrow \frac{C}{x^{\alpha}}. \tag{5}$$

In eq. (5) C is a strictly positive constant, and $\alpha > 1$. Equivalently[27], the corresponding rank-frequency function (number of citations received by the article ranked r) is given by the function G:

$$G:]0, T] \rightarrow [1, +\infty[: r \rightarrow G(r) = \frac{B}{r^{\beta}} \tag{6}$$

with B, $\beta > 0$. The relation between the parameters α and β is

$$\beta = \frac{1}{\alpha - 1}. \tag{7}$$

In the power law model the four Hirsch-type indices are defined as follows:

h is the unique solution of $r = G(r)$,

g is the unique solution of $r^2 = \int_0^r G(s)ds$,

$$A = \frac{1}{h}\int_0^h G(r)dr \quad \text{and} \quad R = \sqrt{\int_0^h G(r)dr}.$$

Note that we do not claim that actual sources follow a power law: we just apply this model as a first approximation of an observed frequency distribution. Assuming further that $\alpha > 2$, we prove the following proposition.

Proposition 2. Assuming a power law model as described above with $\alpha > 2$ or equivalently $0 < \beta < 1$, we have

$$A = \left(\frac{\alpha-1}{\alpha-2}\right)h \quad \text{and} \quad R = \sqrt{\frac{\alpha-1}{\alpha-2}}h, \tag{8}$$

$$A = \left(\frac{\alpha-1}{\alpha-2}\right)^{1/\alpha} g \quad \text{and} \quad R = \left(\frac{\alpha-1}{\alpha-2}\right)^{1/2\alpha} \sqrt{gh}. \tag{9}$$

Proof. A is defined as the average number of citations received by publications belonging to the Hirsch core. Hence

$$A = \frac{1}{h}\int_0^h \frac{B}{r^\beta}dr = \frac{1}{h}B\frac{h^{1-\beta}}{1-\beta}.$$

As $h = B^{1/(\beta+1)}$ (by Theorem C)[3], and by eq. (7) this result implies that

$$A = \frac{1}{h}B\frac{h^{1-\beta}}{1-\beta} = \frac{1}{h}h^{\beta+1+1-\beta}\frac{\alpha-1}{\alpha-2} = \frac{\alpha-1}{\alpha-2}h.$$

This proves the first equality of line (8). It is further shown by Egghe[16] that

$$g = \left(\frac{\alpha-1}{\alpha-2}\right)^{\frac{\alpha-1}{\alpha}} h. \tag{10}$$

Eliminating h from eqs. (8) and (10) yields the first equality of line (9). The corresponding relations for R follow then easily from those for A.

Remark 1. As $\alpha > 2$ eqs. (8) and (9) imply that A and R are always larger than h. Moreover, $A > g$, while R is larger than the geometric average of h and g $\left(\text{this follows from the fact that for } \alpha > 2 \ \left(\frac{\alpha-1}{\alpha-2}\right)^{1/\alpha} > 1\right)$. Note that the power law model yields the same inequalities as in the discrete case.

Remark 2. Eq. (8) or eq. (9) does not prove that h and A, or h and R are linearly related. The reason is that in the power law model $h = T^{1/\alpha}$, where T is the total number of sources (here the total number of publications). Hence the factor $\frac{\alpha-1}{\alpha-2}$ cannot be considered as a constant.

Finally we prove a very remarkable relation, characterizing the h-index in the power law model.

Characterization Theorem. Assuming a power law model as described above with $\alpha > 2$ and denoting by μ the average production (here: total number of citations divided by the total number of articles in the author's publication list) the following relations hold:

$$A = \mu h \quad \text{and} \quad R = \sqrt{\mu}h. \tag{11}$$

Proof. Eqs. (11) follow immediately from equations (8) and the fact that, in the power law model, $\mu = \frac{\alpha-1}{\alpha-2}$ (as shown on page 115 of ref. [27]).

This result shows that in the power law model h is the unique number N such that the average number of citations of the first N publications is equal to the global average multiplied by N. Uniqueness follows from the fact that the average number of citations of the first N publications is a decreasing function of N, while μN is an increasing function of N.

1.7 The *h*-, *A*-, *R*- and *g*-indices are highly correlated in practice

Notwithstanding remark 2 above, we think that in most practical cases the four Hirsch-type indices h, A, R and g are linearly correlated. Indeed, they more or less use the same, highly restricted, data set, and this with similar objectives. In order to investigate this we study in this section a number of practical cases.

Using Egghe's data for Price awardees[16] we calculated the A- and the R-index of each of these colleagues. We did the same for publications in the WoS of a number of physics, chemistry and biology subfields (1996—2005) and of the contribution of four large national research institutes in the WoS (2001—2005). Data were obtained from the China in World Science Series[28−30]. Details of the calculations can be found in the Appendices. Table 1 shows the observed Pearson correlation coefficients (CCs).

Table 1 Correlation coefficients between R and g

Data set	CC (R vs. g)	CC (R/h vs. g/h)
Price awardees	0.998	0.995
Chemistry subfields	0.999	0.998
Biology subfields	0.999	0.997
Physics subfields	0.999	0.998
CAS physics subfields	0.999	0.995
Max Planck physics subfields	0.999	0.997
CNRS physics subfields	0.998	0.995
RAS physics subfields	0.991	0.959

These data speak for themselves: there is no doubt that the R-index and the g-index are highly correlated in practice. The same observation holds for the ratios R/h and g/h. A similar remark (not shown) holds for A and g, but with slightly smaller correlations. We further observe that the CC between R and g is always higher than that between R and h or g and h. The latter two are very similar (see appendices for details).

1.8 A preliminary conclusion

It seems that the g-index and R-index are highly correlated while the latter has a computational advantage. Yet, as a stand-alone index R may be overly sensitive to one article receiving an extremely high number of citations[31]. In the extreme case one may encounter a scientist with an h-index of 1 and an R-index of 10 (any high number). This observation similarly applies to the g-index (in particular when fictitious articles with zero citations are added[16]). For this reason we suggest using the R-index in conjunction with h. Consequently we propose, as a preliminary conclusion, the pair (h, R) as a good indicator for research evaluation. For practical evaluation purposes applying time windows, e.g. a 5-year window, seems advisable. Moreover, the ratio R/h might be an interesting indicator in its own right.

2 An age-dependent indicator: The *AR*-index

In order to overcome the problem that the h-index may never decrease and that scientists may, so to speak, 'rest on their laurels' we propose the following adaptation of the R-index[32].

2.1 Definition: the *AR*-index

If a_j denotes the age of article j we define the age-dependent R-index, denoted by AR, by the following equation:

$$AR = \sqrt{\sum_{j=1}^{h} \frac{cit_j}{a_j}} . \qquad (12)$$

If there are several publications with exactly h citations then we include the most recent ones in the h-core. This means that we include those with the more favorable (cit/a) ratio.

Advantages of the AR-index are clear. Besides taking the actual number of citations into account, it makes also use of the age of the publications. In this way, the h-index is complemented by an index that can actually decrease. Such behavior is, in our opinion, a necessary condition for a good research evaluation indicator. We note that, moreover, the AR-index is based on the h-index as it makes use of the h-core. For the AR-index the inequality $h \leqslant AR$ is not necessarily true anymore, contrary to the corresponding relation involving the R-index (see eq. (4)). We note that calculation of the AR-index only requires the age of the publications in the h-core, besides the data necessary for the calculation of the h-index. This does not make the calculation of the AR-index more difficult than that of the h-index. Note that for source-item relations where age has no meaning this indicator just does not apply. This is somewhat similar to the h-index, which also does not apply for all possible source-item relations.

Favorable points concerning the R-index also apply here. Hence we propose the pair (h, AR) as a good indicator for research evaluation.

2.2 An example

We calculated the AR-index over several years for the articles written by B.C. Brookes after 1971 (WoS publication and citation data on January 1, 2007). Recall that B.C. Brookes was a Price awardee in 1989. He died in 1991. Results are shown in Table 2.

Table 2 Evolution of B.C. Brookes' *AR*-index

Year	*R*-index	*AR*-index
2002	18.60	3.93
2003	18.81	3.89
2004	18.97	3.84
2005	19.13	3.79
2006	19.34	3.76
2007	19.54	3.73

Brookes' h-index over the whole period (2002－2007) stays fixed at h = 12 (hence here $h > AR$). Between 2002 and 2007 his R-index increased by 5% while the AR-index decreased by about 5%. A year written in the first column of Table 2 stands for January 1 of that year. The (average) age of an article on January 1 of year Y is (k-0.5) if the article is published during the year Y-k. Indeed, if an article is published during the year Y-3 then it is, on January 1 of the year Y at least two years, and at most three years old. On average it is 2.5 years old[33]. This is how we calculated the average age of an article in order to obtain the AR-index. Figure 1 illustrates the decrease of Brookes' AR-index over the latest years.

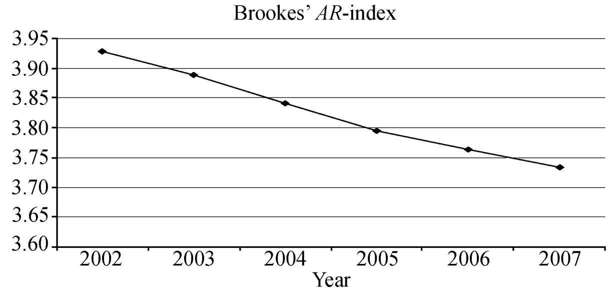

Figure 1 Decrease of Brookes' *AR*-index.

3 Conclusion

Based on the foundation laid by the *h*-index we have introduced the *R*- and *AR*-indices. These new indices eliminate some of the disadvantages of the *h*-index, especially when the two indices are used in combination. The *R*-index measures the *h*-core's citation intensity, while *AR* goes one step further and takes the age of the publications into account. This allows for an index that can actually decrease over time. We propose the pair (*h*, *AR*) as a meaningful scientometric indicator. When using this pair for research evaluation it is suggested to apply a suitable publication and citation window, and not to take the complete career of a scientist into account.

We observe that we did not solve the original problem of replacing the *h*-index by an index that may actually increase and decrease. As a stand-alone index *AR* would have this property, but we are not convinced that a ranking according to the *AR*-index, considered on its own, would be convincing, especially in performance evaluation exercises. An investigation of the properties of the *AR*-index is left for future research.

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Appendix A Price awardees data (bases on WoS, January 2006)
Table of Price awardees

Name	*h*-index	*g*-index	*g*/*h*	*R*	*R*/*h*
Garfield	27	59	2.19	55.21	2.04
Narin	27	40	1.48	37.51	1.39
Braun	25	38	1.52	34.17	1.37
Van Raan	19	27	1.42	24.73	1.30
Glänzel	18	27	1.50	37.85	2.10
Moed	18	27	1.50	27.40	1.52
Schubert	18	30	1.67	25.53	1.42
Small	18	39	2.17	24.37	1.35
Martin	16	27	1.69	25.17	1.57
Egghe	13	19	1.46	24.85	1.91
Ingwersen	13	26	2.00	17.77	1.37
Leydesdorff	13	19	1.46	17.52	1.35
Rousseau	13	15	1.15	14.20	1.09
White	12	25	2.08	23.52	1.96
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.998	0.830	0.852	0.995	

Appendix B Physics subfields (WoS: 1996－2005)

Subfields	*h*	*R*	*g*	*R*/*h*	*g*/*h*
CP symmetry breaking	168	254.32	288	1.51	1.71
Bose Einstein condensation	161	229.45	256	1.43	1.59
Quantum chromodynamics	152	194.15	216	1.28	1.42
String theory	151	211.06	236	1.40	1.56
Dark matter and dark energy	173	248.87	279	1.44	1.61
Black holes	139	170.04	187	1.22	1.35
Neutrino physics	131	217.46	243	1.66	1.85
SNS	152	192.19	212	1.26	1.39
Spintronics	157	220.61	247	1.41	1.57
Semiconductor quantum dots	159	237.92	267	1.50	1.68
Wide band gap diamond semiconductors	131	180.97	202	1.38	1.54
Magnetic materials	188	263.03	296	1.40	1.57
Photo electronic devices	187	249.17	278	1.33	1.49
Magnetic thin films	139	193.37	216	1.39	1.55
Bulk metal glass	130	164.44	182	1.26	1.40
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.999	0.860	0.853	0.998	

Appendix C Chinese Academy of Sciences (CAS): physics subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
CP symmetry breaking	36	67	60.60	2.83	1.68
Bose Einstein condensation	22	28	25.69	1.36	1.17
Quantum chromodynamics	29	44	39.94	1.90	1.38
String theory	16	23	21.91	1.88	1.37
Dark matter and dark energy	27	40	36.74	1.85	1.36
Black holes	21	32	29.34	1.95	1.40
Neutrino physics	19	42	38.00	4.00	2.00
SNS	13	17	16.12	1.54	1.24
Spintronics	20	28	25.69	1.65	1.28
Semiconductor quantum dots	21	29	26.32	1.57	1.25
Wide band gap diamond semiconductors	25	40	36.06	2.08	1.44
Magnetic materials	25	35	32.40	1.68	1.30
Photo electronic devices	35	53	48.06	1.89	1.37
Magnetic thin films	20	28	25.30	1.60	1.26
Bulk metal glass	23	33	30.71	1.78	1.34
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.999	0.930	0.915	0.995	

Appendix D Max Planck Institute: physics subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
CP symmetry breaking	46	97	88.43	3.70	1.92
Bose Einstein condensation	36	66	59.70	2.75	1.66
Quantum chromodynamics	41	83	76.03	3.44	1.85
String theory	31	47	43.49	1.97	1.40
Dark matter and dark energy	51	94	84.20	2.73	1.65
Black holes	45	66	59.62	1.76	1.32
Neutrino physics	32	83	77.77	5.91	2.43
SNS	29	40	37.31	1.66	1.29
Spintronics	31	47	42.04	1.84	1.36
Semiconductor quantum dots	26	40	36.41	1.96	1.40
Wide band gap diamond semiconductors	19	30	28.25	2.21	1.49
Magnetic materials	35	49	45.06	1.66	1.29
Photo electronic devices	32	52	46.99	2.16	1.47
Magnetic thin films	38	56	51.58	1.84	1.36
Bulk metal glass	20	32	28.98	2.10	1.45
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.999	0.850	0.859	0.997	

Appendix E CNRS (France): physics subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
CP symmetry breaking	33	52	47.37	2.06	1.44
Bose Einstein condensation	32	42	38.78	1.47	1.21
Quantum chromodynamics	36	55	50.20	1.94	1.39
String theory	20	35	31.30	2.45	1.57
Dark matter and dark energy	36	54	48.74	1.83	1.35
Black holes	31	42	38.57	1.55	1.24
Neutrino physics	21	34	31.08	2.19	1.48
SNS	35	48	43.47	1.54	1.24
Spintronics	31	51	45.91	2.19	1.48
Semiconductor quantum dots	22	37	33.50	2.32	1.52
Wide band gap diamond semiconductors	25	34	31.62	1.60	1.26
Magnetic materials	38	57	51.94	1.87	1.37
Photo electronic devices	32	44	40.00	1.56	1.25
Magnetic thin films	34	50	46.28	1.85	1.36
Bulk metal glass	26	37	34.21	1.73	1.32
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.998	0.920	0.912	0.995	

Appendix F Russian Academy of Science (RAS): physics subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
CP symmetry breaking	25	39	35.36	2.00	1.41
Bose Einstein condensation	20	28	26.08	1.70	1.30
Quantum chromodynamics	18	24	22.45	1.56	1.25
String theory	9	12	11.22	1.56	1.25
Dark matter and dark energy	20	38	34.93	3.05	1.75
Black holes	17	31	28.27	2.76	1.66
Neutrino physics	27	41	37.83	1.96	1.40
SNS	19	29	26.15	1.89	1.38
Spintronics	23	37	33.57	2.13	1.46
Semiconductor quantum dots	18	30	27.50	2.33	1.53
Wide band gap diamond semiconductors	18	21	23.24	1.67	1.29
Magnetic materials	20	34	30.98	2.40	1.55
Photo electronic devices	21	36	32.73	2.43	1.56
Magnetic thin films	18	27	24.37	1.83	1.35
Bulk metal glass	14	17	16.31	1.36	1.16
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.991	0.920	0.902	0.959	

Appendix G Chemistry subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
Asymmetric catalysis and synthesis	126	198	157.95	1.57	1.25
Single molecule	162	279	212.60	1.72	1.31
Nanoporous Materials	135	263	188.43	1.95	1.40
Photonic Crystal	97	189	135.40	1.95	1.40
Molecular devices	132	240	177.99	1.82	1.35
Chemical dynamics	69	128	93.98	1.86	1.36
Alkene Metathesis	99	185	135.33	1.87	1.37
Combinatorial chemistry	115	256	171.58	2.23	1.49
Living Radical Polymerization	148	261	196.54	1.76	1.33
Density functional theory	128	276	187.96	2.16	1.47
Fuel cells	68	118	89.58	1.74	1.32
Enzyme catalysis	100	152	123.29	1.52	1.23
Supramolecule and self-assembly	132	259	184.90	1.96	1.40
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.999	0.975	0.971	0.998	

Appendix H Biology subfields (WoS: 2001－2005)

Subfields	*h*	*g*	*R*	*g*/*h*	*R*/*h*
Stem cell	194	338	256.07	1.47	1.32
Cell mobility	156	251	197.88	1.41	1.27
Phylogenetics	150	302	212.84	1.59	1.42
Cell proliferation	177	294	228.12	1.44	1.29
Cell cycle	191	312	244.11	1.42	1.28
Cell and signal transduction	302	528	399.32	1.47	1.32
Epigenetics	203	371	274.43	1.51	1.35
Bio-chip	168	329	235.10	1.57	1.40
Apoptosis	292	587	414.01	1.59	1.42
Cell membrane and membrane traffic	196	336	256.62	1.46	1.31
Cytoskeleton	159	267	206.04	1.44	1.30
Genetic polymorphisms	122	216	162.33	1.48	1.33
Regulation and gene express	235	405	308.50	1.46	1.31
Cell mitosis	181	313	238.02	1.47	1.32
Genomics	153	332	225.38	1.65	1.47
MicroRNA	141	308	208.39	1.63	1.48
Bioinformatics	160	344	234.61	1.64	1.47
Correlation coefficients	*R* vs. *g*	*R* vs. *h*	*g* vs. *h*	*R*/*h* vs. *g*/*h*	
CC	0.999	0.980	0.981	0.998	

1 Hirsch J E. An index to quantify an individual's scientific research output. Proc Natl Acad Sci USA, 2005, 102(46): 16569－16572
2 Braun T, Glänzel W, Schubert A. A Hirsch-type index for journals. The Scientist, 2005, 19(22): 8
3 Egghe L, Rousseau R. An informetric model for the Hirsch index. 2006, Scientometrics, 69(1): 121－129
4 Rousseau R. A case study: Evolution of JASIS' *h*-index. Science Focus (in Chinese), 2006, 1(1): 16－17 (English version available at E-LIS, code 5430)
5 Banks M G. An extension of the Hirsch index: Indexing scientific topics and compounds. Scientometrics, 2006, 69(1): 161－168
6 The STIMULATE - 6 Group. The Hirsch index applied to topics of interest to developing countries. First Monday, 2007, 12(2) (http://www.firstmonday.org/issues/issue12 2/stimulate/)
7 Liu Y, Rousseau R. Hirsch-type indices and library management: The case of Tongji University Library. Proceedings of the 11th ISSI Conference, 2007, Madrid (to appear)
8 Edwards A W F. System to rank scientists was pedalled by Jeffreys. Nature, 2005, 437(7061): 951
9 Glänzel W. On the opportunities and limitations of the H-index. Science Focus (in Chinese), 2006, 1(1): 10－11
10 Rousseau R. The influence of missing publications on the Hirsch index. Journal of Informetrics, 2007, 1(1): 2－7
11 van Raan A F J. Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. Scientometrics, 2006, 67(3): 491－502
12 Ball P. Index aims for fair ranking of scientists. Nature, 2005, 436(7053): 900
13 Bar-Ilan J. H-index for price medalists revisited. ISSI Newsletter, 2006, 2(1): 3－5
14 Bornmann L, Daniel, H D. Does the h-index for ranking of scientists really work? Scientometrics, 2005, 65(3): 391－392
15 Cronin B, Meho L I. Using the h-index to rank influential information scientists. J Am Soc Infor Sci Technol, 2006, 57(9): 1275－1278
16 Egghe L. Theory and practice of the *g*-index. Scientometrics, 2006, 69(1): 131－152
17 Glänzel W, Persson O. H-index for Price medalists. ISSI Newsletter, 2005, 1(4): 5－18
18 Liang L. *h*-index sequence and h-index matrix: Constructions and applications. Scientometrics, 2006, 69(1): 153－159
19 Batista P D, Campiteli M G, Kinouchi O, et al. Is it possible to compare researchers with different scientific interests? Scientometrics, 2006, 68(1): 179－189
20 Rousseau R. Simple models and the corresponding *h*- and *g*-index. Science Technology Development. 2006 (to appear)(see also E-LIS: code ID 6153)
21 Burrell Q L. Hirsch's h-index: A stochastic model. J Informetrics, 2007, 1(1): 16－25
22 Glänzel W. On the h-index—A mathematical approach to a new measure of publication activity and citation impact. Scientometrics, 2006, 67(2): 315－321
23 Egghe L. How to improve the h-index. The Scientist, 2006, 20(3): 14
24 Egghe L. An improvement of the H-index: The G-index. ISSI Newsletter, 2006, 2(1): 8－9
25 Kosmulski M. A new Hirsch-type index saves time and works equally well as the original h-index. ISSI Newsletter, 2006, 2(3): 4－6
26 Jin B H. H-index: An evaluation indicator proposed by scientist. Science Focus (in Chinese), 2006, 1(1): 8－9
27 Egghe L. Power Laws in the Information Production Process: Lotkaian Informetrics. Oxford (UK): Elsevier, 2005
28 Jin B H, et al. Analysis of the development of important subfields in chemistry. China in World Science Series Report 3 (in Chinese). Basic Research Department of the Ministry of Science & Technology and National Science Library of CAS, 2005
29 Jin B H, et al. Analysis of the development of important subfields in cell biology and genomics. China in World Science Series Report 5 (in Chinese). Basic Research Department of the Ministry of Science & Technology and National Science Library of CAS, 2006
30 Jin B H, et al. Analysis of the development of important subfields in physics. China in World Science Series Report 6 (in Chinese). Basic Research Department of the Ministry of Science & Technology and National Science Library of CAS, 2006
31 Rousseau R. New developments related to the Hirsch index. Science Focus (in Chinese), 2006,1(4): 23－25 (English version available at E-LIS, code 6376)
32 Jin B H. The AR-index: Complementing the h-index. ISSI Newsletter, 2007, 3(1) (to appear)
33 Rousseau R. Timelines in citation research. J Am Soc Infor Sci Technol, 2006, 57(10): 1404－1405

Comments

The authors present an interesting paper on new measures complementing the *h*-index. The goal of the paper is to overcome shortcomings and limitations of the Hirsch index which partially result from the insensitivity of this measure to changes of the number of citations received by the top publications.

The paper begins with a profound overview of advantages and disadvantages of the *h*-index. After this summary, the new measures—the *A*-index and the *R*-index—are introduced. Basic properties as well as their relationship with Hirsch's *h*-index and Egghe's *g*-index in the power law model are analysed. Finally, the age-dependent *AR* index is introduced; this measure takes into account the age of publications, and is therefore less sensitive to the age of scientists, as well.

The paper is closed by a discussion and an appendix with applications of the *h*-index and the new measures to individual scientists, subject fields and institutions.

I have one minor comment. The authors should add the definition of the *A*-index instead of referring to Jin (2007) and mention the date for which the *h*-index has been calculated since the *h*-index is continuously changing.
In all, this is an excellent paper that deserves to be published in any relevant international journal.

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