BRIEF COMMUNICATION

# What Do We Know About the *h* Index?

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**Jorge Hirsch (2005a, 2005b) recently proposed the *h* index to quantify the research output of individual scientists. The new index has attracted a lot of attention in the scientific community. The claim that the *h* index in a single number provides a good representation of the scientific lifetime achievement of a scientist as well as the (supposed) simple calculation of the *h* index using common literature databases lead to the danger of improper use of the index. We describe the advantages and disadvantages of the *h* index and summarize the studies on the convergent validity of this index. We also introduce corrections and complements as well as single-number alternatives to the *h* index.**

## Definition and Advantages of the *h* Index

In evaluative bibliometrics, the measurement of research performance at the micro level, that is, at the level of an individual scientists, is viewed as problematic (Cole, 1989). The reasons are that (a) a sufficiently large publication output produced in a manageable time span is necessary to obtain statistically reliable indicators, and (b) research productivity, publication numbers, and citation impact are not necessarily correlated variables (Glänzel, 2006b). However, due to scarce resources the quantification of scientific performance is needed for evaluation and comparison purposes to inform funding or tenure decisions (Ball, 2005; Hirsch, 2005a).

Jorge Hirsch (2005a, 2005b) recently proposed a new research performance indicator that is designed for application at the micro level. The Hirsch index, or *h* index, quantifies as a single-number criterion the scientific output of a single researcher. Hirsch's index is an original and simple new measure incorporating both quantity and visibility of publications (Egghe, 2006b; Egghe & Rousseau, 2006; Moed, 2005b; van Raan, 2006): "A scientist has index $h$ if $h$ of his or her $N_p$ papers have at least $h$ citations each and the other $(N_p - h)$ papers have fewer than $\leq h$ citations each" (Hirsch, 2005a, p. 16569; see also Rousseau, 2006b, 2006c). A $h$ index of 40 means, for example, that a scientist has published 40 papers that each had at least 40 citations. A scientist's $h$ index will never decrease (Sidiropoulos, Katsaros, & Manolopoulos, 2006); an increase is to be expected as new (high-impact) papers are published, as "sleeping beauties" (van Raan, 2004b) come to life, and as the scientist's papers attract citations (Cronin & Meho, 2006; Hirsch, 2005a). $h = 0$ characterizes inactive scientific authors (Glänzel, 2006b) that have at best published papers that have had no visible impact.

The proposed new measure of research performance was quickly taken up by *Nature* (Ball, 2005) and *Science* (Anonymous, 2005). The idea of ranking scientists by a single number and the alleged advantages that the $h$ index has over other citation-based indices (for example, total number of papers, total number of citations, or citations per paper) attracted the attention of scientific news editors. The $h$ index is seen to have the advantage that it gives a robust estimate of the broad impact of a scientist's cumulative research contributions (Hirsch, 2005a). This means that the $h$ index is insensitive to a set of lowly cited (noncited) papers or to one or several highly cited papers: A scientist with very few highly cited papers (a "one-hit wonder") or, alternatively, many lowly cited papers will have a weak $h$ index (Cronin & Meho, 2006; Egghe, 2006b, 2006c). As a rule, the index favors enduring performers that publish a continuous stream of papers with lasting and above-average impact (Anonymous, 2005).

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A further advantage seen for the $h$ index is that the necessary data for calculation is easy to access in the Thomson Scientific (Philadelphia, Pennsylvania) Web of Science database without the need for any off-line data processing (Batista, Campiteli, Kinouchi, & Martinez, 2005). The index can be calculated by sorting a set of papers (coauthored by one scientist) using the "times cited" option: scroll down the Web of Science output until the rank of the paper (in terms of citations) is greater than the number of citations that it has. The preceding rank equals the $h$ index (Kelly & Jennions, 2006). According to Glänzel (2006b), any Web of Science document type can be considered when determining the $h$ index, because the $h$ index is not changed by adding typical lowly cited papers (such as meeting abstracts) or typical highly cited papers (such as reviews).

## Application of the *h* Index

Jorge Hirsch (2005a) originally suggested the $h$ index for application at the micro level, that is, as a measure to quantify the scientific output of a single researcher (see, for example, the $h$ indices calculated by Garfield, 2006, for Nobel Prize recipients, and Glänzel & Persson, 2005, for Derek J. de Solla Price Medalists). However, the $h$ index can be used not only for the lifetime achievements of a single researcher but can be applied to any (more extensive) publication set (Rousseau, 2006b). Van Raan (2006) calculates the $h$ index for university research groups in chemistry and chemical engineering in the Netherlands (van Raan's study is described in greater detail in the following section). With calculation of the $h$ index for individual research groups, van Raan is applying the index for quantification of scientific performance no longer at the micro but at the meso level.

Braun, Glänzel, and Schubert (2005) propose a Hirsch-type index for evaluating the scientific impact of journals as a robust alternative indicator that is an advantageous complement to journal impact factors (see also Braun, Glänzel, & Schubert, 2006; Sidiropoulos et al., 2006). The journal $h$ index can be calculated as follows: "Retrieving all source items of a given journal from a given year and sorting them by the number of times cited, it is easy to find the highest rank number which is still lower than the corresponding times-cited value. This is exactly the $h$-index of the journal for the given year" (Braun et al., 2005, p. 8; for a critique of the Hirsch-type index, see Vanclay, 2006). Since the $h$ index can not be larger than the number of papers it is based on, Braun et al. (2005) did not include in their exemplary calculations of the $h$ index of various journals with a high visibility in science (e.g., *Science*, $h = 13$, *Nature*, $h = 10$; source year 2001) the journals *Review of Immunology* (24 papers in 2001) and *Annual Review of Biochemistry* (23 papers in 2001). To avoid excluding certain journals for comparative purposes and to calculate a journal $h$ index whose value is largely independent of the number of papers published in a journal, Rousseau (2006a) proposes calculation of a relative journal $h$ index, in that the $h$ index is divided by the number of papers published in the journal.

Banks (2006) applies the $h$ index to the case of interesting topics and compounds: Bank's $h - b$ index is found by entering a topic (search string, like "superstring" or "teleportation") or compound (name or chemical formula) into the Web of Science database and then ordering the results in terms of citations, by largest first. The $h - b$ index is then defined in the same manner as the $h$ index. With calculation of the $h - b$ index, it can be determined—while at the same time considering the previous research time on a topic or compound—how much work has already been done on certain topics or compounds, what the "hot topics" (or "older topics") of interest are, or what topic or compound is mainstream research at the present time. Based on his calculations, for example, Banks (2006) identifies "carbon nanotubes" ($h - b = 167$) and "nanowires" ($h - b = 105$) as current, revolutionary topics in physics, as a huge amount of work has been conducted in these areas in a very short period of time.

## Convergent Validity of the *h* Index

When a new indicator is proposed as a measure of the output of a scientist's work, there is always the question of the convergent validity of the indicator: How does it relate to other (advanced) bibliometric indicators and to the outcomes of peer review, both of which are standard means of evaluating research performance? So far, a series of analyses has been carried out to examine the convergent validity of the $h$ index in different fields. Hirsch's (2005a) own computations of the $h$ index for physicists that received the Nobel Prize in the last 20 years, for elected members of the National Academy of Sciences (Washington, DC) in physics and astronomy in 2005, and for the most highly cited scientists in the fields of biological and biomedical sciences (see Thomson Scientific's ISI HighlyCited.com) in the period 1983–2002 indicate "that the index $h$ is a stable and consistent estimator of scientific achievement" (p. 16572). Like van Raan (2004a) does for his "crown indicator," Hirsch (2005a) formulates for the $h$ index threshold values, based on which the level of scientific success of physicists can be determined:

> An $h$ index of 20 after 20 years of scientific activity characterizes a successful scientist … An $h$ index of 40 after 20 years of scientific activity characterizes outstanding scientists, likely to be found only at the top universities or major research laboratories … An $h$ index of 60 after 20 years, or 90 after 30 years characterizes truly unique individuals. (p. 16571)

Bornmann and Daniel (2006) investigated committee peer review for awarding long-term fellowships to post-doctoral researchers as practiced by the Boehringer Ingelheim Fonds (BIF) – an international foundation for the promotion of basic research in biomedicine (see also Bornmann & Daniel, 2005a, 2005c). According to Fröhlich (2001), managing director of the BIF, applicants that demonstrate excellence in scientific work are selected for the fellowships by the BIF Board of Trustees (seven internationally renowned scientists); otherwise, the applicants are rejected. To demonstrate that the


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*h* index is a useful yardstick to compare different scientists competing for research fellowships, the index should be strongly related to the assessment by peers (Cole, 1989; Moed, 2005a). The results of the study by Bornmann and Daniel (2005b) show that the *h* indices of approved applicants are on average higher than those of rejected applicants. Therefore, the results suggest that the *h* index is a promising rough measurement of the quality of a scientist's work as it is judged by internationally renowned scientists in the field of biomedical sciences.

Cronin and Meho (2006) apply the *h* index to the literature in the information sciences. Rankings of influential US information scientists based on raw citation counts are compared with those based on *h* indices. As the findings show a strong positive correlation between the two sets of rankings, Cronin and Meho (2006) suggest that the *h* index can be used to "express the broad impact of a scholar's research output over time" (p. 1275). In their study, Cronin and Meho built rankings of the information scientists both using *h* indices in which self-citations were included in the calculation and *h* indices in which self-citations were excluded from the calculation. Comparison of the two rankings revealed that, in general, the elimination of self-citations does not much influence the rank ordering of the scientists.

To analyze the convergent validity of the *h* index, van Raan (2006) used the results of an evaluation study covering 147 university research groups in chemistry and chemical engineering in the Netherlands (total number of publications about 18,000). Van Raan calculated correlations between the *h* index and several standard bibliometric indicators as well as the results of peer-review judgment of the groups. The results show that the *h* index and the standard bibliometric indicators "both relate in a quite comparable way with peer judgments" (van Raan, 2006, p. 491). Kelly and Jennions (2006) quantified the publication output of 187 individual editorial board members (ecologists and evolutionary biologists) of seven journals and measured the *h* index of each. The calculation of the relationship between *h* index and total publication output shows that they are closely correlated. In a second step of their analysis, Kelly and Jennions (2006) inspected a sample of 18 evolutionists and ecologists ranked by Thompson Scientific as "highly cited." Their publication output and citation impact yielded a mean *h* index of 45.

While the studies presented above confirm the convergent validity of the *h* index in general, a study by Lehmann, Jackson, and Lautrup (2005) raises some doubt as to the accuracy of the index for measuring scientific performance. The authors present a general Bayesian method for quantifying the statistical reliability of some one-dimensional measures of scientific quality based on citation and publication data. As the database, Lehmann et al. (2005) used papers in high-energy physics from the Stanford Physics Information Retrieval System database (SPIRES; http://www. slac. stanford.edu/spires/hep/). The results of the statistical analyses show that the mean, median, and maximum numbers of citations are reliable and permit accurate measures of scientific performance. The *h* index is shown to lack the necessary accuracy and precision to be useful: The measure does not lead to a reliable conclusion as to the quality of a scientist's production regarding his or her publication and citation record.

## Disadvantages of the *h* Index

Because of the many advantages that the *h* index offers as an evaluative bibliometric measure, and due to the simplicity of calculation using the Web of Science database, the *h* index has found widespread positive reception. As an alternative to other citation-based indices that could be used to measure research performance, however, some critical objections to the new index have been raised. Van Raan (2006), for instance, states, "it is not wise to force the assessment of researchers or of research groups into just one measure, because it reinforces the opinion … that scientific performance can be expressed simply by one note" (p. 501). Several indicators are necessary in order to illuminate different aspects of performance (van Raan) and to provide a more adequate and multifaceted picture of reality (Glänzel, 2006b). The proposed disadvantage of the *h* index to quantify as a single-number criterion the researcher's scientific output can therefore also be seen as a disadvantage: It "crashes the multidimensional space of bibliometrics into one single dimension" (Glänzel, 2006a, p. 320). This possibility to reduce multidimensional bibliometrics to one single index has led some authors to state *h* index threshold values that are to be expected of successful scientists in physics and biology (Hirsch, 2005a), and ecology and evolutionary biology (Kelly & Jennions, 2006). In our view, however, the use of these threshold values for categorization of the research performance of individual scientists is premature. There is still a need for a great deal of research to increase our understanding of the *h* index in different fields of science.

According to Hirsch (2005a), the *h* index for a scientist can be found very easily by ordering papers by "times cited" in the Web of Science database. However, when searching for papers by a scientist by means of only the author search field in the Web of Science database in order to calculate the *h* index from citations of these papers, it cannot be ruled out with certainty that papers by a different scientist of the same name are entering into the calculation. For this reason we recommend calculating the *h* index on the basis of a complete list of publications that is authorized by the scientist himself or herself. Strictly speaking, the *h* index for a scientist can be found easily in Web of Science only if the scientist can be identified uniquely by name or if accurate publication lists can be pulled up in Web of Science by using a combination of the author name and address, or affiliation, search fields.

When calculating *h* indices via publications and citations in the Web of Science database, it must also be considered that the real publication and citation data can be much higher (Roediger, 2006). Only the source journals selected by Thomson Scientific are used in the database, and unclear citations (for example, "to appear" or "forthcoming"), incorrect citations (such as incorrect starting page number by the citing author), and publications not indexed by Thomson


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Scientific (e.g., books and conference proceedings) are not counted (Cronin & Meho, 2006; Egghe, 2006d). Completing publication lists and manually calculating citation counts require labor-intensive processes. Cronin and Meho show, taking the example of the information sciences, what different results can be expected when comparing a sample of *h* indices derived from Web of Science with *h* indices generated manually.

According to Sidiropoulos et al. (2006), the *h* index "has various shortcomings, mainly of its inability to differentiate between active and inactive (or retired) scientists and its weakness to differentiate between significant works in the past (but not any more) and the works which are 'trendy' or the works which continue to shape the scientific thinking" (p. 16). Since *h* values (that is, published papers and the citations papers receive) increase over time (Egghe, 2006a; Hirsch, 2005a), it is apparent that a scientist's *h* index depends on the person's scientific age (that is, years publishing, Glänzel, 2006b; Roediger, 2006). Therefore, in ranking scientists, the *h* index always puts newcomers at a disadvantage and older, well-established scientists at a advantage (Cronin & Meho, 2006; Glänzel, 2006b). It should also be considered that when using the *h* index for comparison purposes, there are discipline-dependent citation patterns in science (Bornmann & Daniel, in press; Hirsch, 2005a) that are determined by the average number of citations in a paper in a given research field, the average number of papers produced by each scientist in the field, the size of the field (number of scientists), and the attractiveness of the research area (mainstream or nonmainstream area). Because of these discipline-dependent citation conventions, higher *h* indices can be expected in some areas of research than in others (Iglesias & Pecharromán, 2006). For instance, citations per paper within the natural sciences can vary by a factor of up to ten (Bowman & Marx, 2006). With the value of the *h* index being discipline and time-dependent, without corresponding standardization the *h* index should be used to compare the relative importance of scientists only if they are of similar (scientific) age and work in similar disciplines (Kelly & Jennions, 2006; Sidiropoulos et al., 2006).

## New Indices Based on the *h* Index

Due to the above-mentioned disadvantages of the *h* index to quantify the scientific output of a scientist, a number of corrections and complementary indexes to the *h* index, as well as single-number alternatives (for example the *g* index), have already been put forward. Some of the modifications and complements go back to Hirsch (2005a) himself: To correct the *h* index for self-citations, for example, "one would consider the papers with number of citations just $>h$ and count the number of self-citations in each. If a paper with $h + n$ citations has $>n$ self-citations, it would be dropped from the *h* count, and *h* would drop by 1" (p. 16571). In order to account for the number of years of a scientist's career to date, Hirsch (2005a) divides the *h* value by the number of years since an author's first paper to generate the value *m*. As an alternative to *m* it is possible to calculate the *h* index not for a lifetime contribution but for a definite time period (for example, for a single publication year and/or citation year). Taber (2005) calls an index of this type *c* if it refers to the most recent calendar year.

Batista et al. (2005) propose an $h_I$ index that is complementary to *h*; "it lifts the *h* degeneracy and has the advantage of being less sensitive to different research fields. This allows a less biased comparison due to the consideration of coauthorship" (Batista et al., 2005; see also Iglesias & Pecharromán, 2006). Assuming that the coauthorship behavior is characteristic of each research field, Batista and colleagues "divide *h* by the mean number of researchers in the *h* publications, $\langle N_a \rangle = N_a^{(T)}/h$, where $N_a^{(T)}$ is the total number of authors (author multiple occurrences are allowed) in the considered *h* papers" (Batista, Campiteli, & Kinouchi, 2006, p. 184). Hirsch (2005a) similarly proposed normalization of *h* by a factor that reflects the average number of coauthors. Batista et al. (2006) obtained rank plots of *h* and $h_I$ values for four fields of scientific research in Brazil. The results show that contrasting to the *h*-index curve, "the $h_I$ index rank plots collapse into a single curve allowing comparison among different research areas" (Batista et al., 2006, p. 179).

Jin (2006) and Egghe (2006b) have each proposed an alternative to the *h* index that is supposed to be more sensitive to the level of highly cited papers. Both authors see the insensitivity of the *h* index to one or several highly cited papers not as an advantage but as a drawback. In their opinion, "a measure which should indicate the overall quality of a scientist or of a journal should deal with the performance of the top articles" (Egghe, 2006c). Jin's (2006) index is defined as the average number of citations received by articles in the Hirsch core (this is the articles on rank smaller than or equal to *h*). Rousseau (2006b) calls Jin's (2006) proposal the *a* index. In order to account for the performance of highly cited papers in an index, Egghe (2006b; 2006c) proposes a modification of the *h* index called the *g* index. The *g* index is "defined as the highest number, *g*, of papers that together received $g^2$ or more citations. In other words, the higher the number of citations in the top class that skew the citation distribution, the higher the *g* score" (Egghe, 2006b; see also Egghe, 2006d).

## Conclusion

Because of the many advantages over other bibliometric measures that the *h* index offers as an evaluative measure for assessing the research output of scientists and due to its (supposed) simplicity of calculation based on the Web of Science database, the *h* index has been well received in the scientific community. According to Glänzel (2006a) "the strength of this index lies in the potential application to the assessment of small paper sets where other, traditional bibliometric indicators often fail or at least where their application proved … problematic" (p. 320).

The findings by Hirsch (2005a), Cronin and Meho (2006), Bornmann and Daniel (2005b), van Raan (2006), and Kelly and Jennions (2006) on the convergent validity of the *h* index in different research fields indicate that the *h* index is a valid indicator for research performance at the micro and meso levels. However, Lehmann et al. (2005) found that the *h* index lacks the necessary accuracy and precision to be useful. As there has as yet been no thorough validation of the *h* index—that is, cross-discipline validation on the basis of broad statistical data—for various areas of application, the *h* index with the current state of research should not (yet) be used as a criterion to inform decision making in science (the same holds, of course, for the many complementary indices, modifications, and single-number alternatives).

Only when these studies have been conducted and can confirm the validity of the *h* index should the new measure be implemented. However, as the *h* index has some disadvantages, just as do many other evaluative bibliometric indicators, it should, for evaluative purposes, *always* be applied as an addition and not as a substitute (Egghe & Rousseau, 2006; Glänzel, 2006b) for other indicators that have become established standards in recent years (van Raan, 2004a).

## References


Anonymous (2005). Data Point. Science, 309(5738), 1181.

Ball, P. (2005). Index aims for fair ranking of scientists. Nature, 436(7053), 900.

Banks, M.G. (2006). An extension of the Hirsch Index: Indexing scientific topics and compounds. Retrieved June 20, 2006, from http://www.arxiv.org/abs/physics/0604216

Batista, P.D., Campiteli, M.G., & Kinouchi, O. (2006). Is it possible to compare researchers with different scientific interests? Scientometrics, 68(1), 179–189.

Batista, P.D., Campiteli, M.G., Kinouchi, O., & Martinez, A.S. (2005). Universal behavior of a research productivity index. Retrieved June 12, 2006, from http://arxiv.org/abs/physics/0510142

Bornmann, L., & Daniel, H.-D. (2005a). Committee peer review at an international research foundation: Predictive validity and fairness of selection decisions on postgraduate fellowship applications. Research Evaluation, 14(1), 15–20.

Bornmann, L., & Daniel, H.-D. (2005b). Does the *h*-index for ranking of scientists really work? Scientometrics, 65(3), 391–392.

Bornmann, L., & Daniel, H.-D. (2005c). Selection of research fellowship recipients by committee peer review. Analysis of reliability, fairness, and predictive validity of Board of Trustees' decisions. Scientometrics, 63(2), 297–320.

Bornmann, L., & Daniel, H.-D. (2006). Selecting scientific excellence through committee peer review: A citation analysis of publications previously published to approval or rejection of post-doctoral research fellowship applicants. Scientometrics, 68(3), 427–440.

Bornmann, L., & Daniel, H.-D. (in press). What do citation counts measure? A review of studies on citing behavior. Journal of Documentation.

Bowman, B., & Marx, W. (2006). Der Hirsch-Index [The Hirsch Index]. Retrieved June 21, 2006, from http://www.biochem.mpg.de/iv/Hirsch_Index_dt.pdf

Braun, T., Glänzel, W., & Schubert, A. (2005). A Hirsch-type index for journals. The Scientist, 19(22), 8.

Braun, T., Glänzel, W., & Schubert, A. (2006). A Hirsch-type index for journals. Scientometrics, 69(1), 169–173.

Cole, S. (1989). Citations and the evaluation of individual scientists. Trends in Biochemical Sciences, 14(1), 9–13.

Cronin, B., & Meho, L. (2006). Using the *h*-index to rank influential information scientists. Journal of the American Society for Information Science and Technology, 57(9), 1275–1278.

Egghe, L. (2006a). Dynamic *h*-index: the Hirsch index in function of time. Retrieved June 12, 2006, from http://doclib.uhasselt.be/dspace/handle/1942/980

Egghe, L. (2006b). How to improve the *h*-index? The Scientist, 20(3), 14.

Egghe, L. (2006c). An improvement of the *h*-index: the *g*-index. Retrieved June 12, 2006, from http://doclib.uhasselt.be/dspace/handle/1942/983

Egghe, L. (2006d). Theory and practise of the *g*-index. Scientometrics, 69(1), 131–152.

Egghe, L., & Rousseau, R. (2006). An informetric model for the Hirsch-index. Scientometrics, 69(1), 121–129.

Fröhlich, H. (2001). It all depends on the individuals. Research promotion: A balanced system of control. B.I.F. Futura, 16(2), 69–77.

Garfield, E. (2006). Identifying Nobel class scientists and the uncertainties thereof. Retrieved June 20, 2006, from http://www.garfield.library.upenn.edu/papers/lund2006.pdf

Glänzel, W. (2006a). On the *h*-index: A mathematical approach to a new measure of publication activity and citation impact. Scientometrics, 67(2), 315–321.

Glänzel, W. (2006b). On the opportunities and limitations of the *h*-index. Science Focus, 1(1), 10–11.

Glänzel, W., & Persson, O. (2005). *h*-index for Price Medalists. ISSI newsletter, 1(4), 15–18.

Hirsch, J.E. (2005a). An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences, USA, 102(46), 16569–16572.

Hirsch, J.E. (2005b). An index to quantify an individual's scientific research output. Retrieved July 20, 2006, from http://xxx.arxiv.org/abs/physics/0508025

Iglesias, J.E., & Pecharromán, C. (2006). Scaling the *h*-index for different scientific ISI fields. Retrieved August 7, 2006, from http://arxiv.org/abs/physics/0607224

Jin, B.H. (2006). *H*-index: An evaluation indicator proposed by scientist. Science Focus, 1(1), 8–9.

Kelly, C.D., & Jennions, M.D. (2006). The *h*-index and career assessment by numbers. TRENDS in Ecology & Evolution, 21(4), 167–170.

Lehmann, S., Jackson, A.D., & Lautrup, B.E. (2005). Measures and mismeasures of scientific quality. Retrieved June 12, 2006, from http://arxiv.org/abs/physics/0512238

Moed, H.F. (2005a). Citation analysis in research evaluation. Dordrecht, The Netherlands: Springer.

Moed, H.F. (2005b). Hirsch Index is a creative and appealing construct but be cautious when using it to evaluate individual scholars. Retrieved June 17, 2006, from http://www.cwts.nl/hm/Comments_on_Hirsch_Index_2005_12_16.pdf

Roediger, H.L., III (2006). The *h*-index in science: A new measure of scholarly contribution. Observer: The Academic Observer, 19(4).

Rousseau, R. (2006a). A case study: Evolution of JASIS' Hirsch index. Retrieved June 17, 2006, from http://eprints.rclis.org/archive/00005430/

Rousseau, R. (2006b). New developments related to the Hirsch index. Retrieved June 12, 2006, from http://eprints.rclis.org/archive/00006376/

Rousseau, R. (2006c). Simple models and the corresponding *h*- and *g*-index. Retrieved June 12, 2006, from http://eprints.rclis.org/archive/00006153/

Sidiropoulos, A., Katsaros, D., & Manolopoulos, Y. (2006). Generalized *h*-index for disclosing latent facts in citation networks. Retrieved August 6, 2006, from http://arxiv.org/abs/cs.DL/0607066

Taber, D.F. (2005). Quantifying publication impact. Science, 309(5744), 2166.

van Raan, A.F.J. (2004a). Measuring science. Capita selecta of current main issues. In H.F. Moed, W. Glänzel, & U. Schmoch (Eds.), Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems (pp. 19–50). Dordrecht, The Netherlands: Kluwer Academic Publishers.

van Raan, A.F.J. (2004b). Sleeping Beauties in science. Scientometrics, 59(3), 467–472.

van Raan, A.F.J. (2006). Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. Scientometrics, 67(3), 491–502.

Vanclay, J.K. (2006). Refining the *h*-index. The Scientist, 20(7), 14–15.




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