Two H-mixed Synthetic Indices for the Assessment of Research Performance

Fred Y. Ye[*,**]

Abstract

The author proposes two h-mixed synthetic indices, S=100×1g(h×CPP) *and* T=100×1g(R×h×CPP)*, for the assessment of research performance, where CPP stands for citations per publication, h for h-index, and R for R-index, the square root of total number of citations in the Hirsch core* (C_h)*. Like their components that respectively measure average citations of all publications, publication output and impact, and total number of citations in the Hirsch core, the h-mixed synthetic indices S and T use readily accessible data to produce a holistic measurement of academic achievement. Higher values correspond to greater academic achievement. The S and T indices are stratified by values of 100 to indicate varying degrees of achievement, where S<100 or T<100 indicates poor levels.*

Keywords: Synthetic Index; H-index; H-mixed Index; Academic Assessment

1. Introduction

Among commonly used indices for academic assessment, CPP (citations per publication) is widely regarded as a simple and reliable indicator that indicates impact or visibility. Moreover, CPP forms the foundation of other bibliometric indicators, like those developed at the CWTS (Center for Science and Technology Studies in the Netherlands): the Crown index CPP/FCSm and CPP/JCSm (Moed, De Bruin, & Van Leeuwen, 1995; Van Raan, 2005). So did other relative indicators (Vinkler, 2003).

When Hirsh introduced h-index (2005), academics were quick to note the strengths and weaknesses of the simple indicator for academic assessment. As stated by Hirsch (2005), Glänzel (2006), Egghe (2007), Costas and Bordons (2007) and Rousseau (2008), the strengths of the h-index can be summarized as follows:

- It is a mathematically simple index and better than total number of publications or total number of citations alone.
- It accounts for both quantity and quality by incorporating both publication output and citation impact and allowing for the inclusion

* Professor, Department of Information Resources Management, Zhejiang University, Hangzhou (China)
** Visiting Professor, Institute of Scientific and Technical Information of China, Beijing (China)
E-mail: yye@zju.edu.cn

of all document types.

- It encourages high quality (or at least highly visible) publications and discourages the publication of unimportant works.
- It can be applied to individual scientists as well as to any level of aggregation from research institute to university to country.
- Single peaks (top publications) have hardly any impact, and an increase in publications alone does not have an immediate effect on the h-index.
- It is a robust indicator in the sense that publications with few citations and small errors in data collection have little or no effect.
- Requisite data are easily obtained via databases like ISI Web of Science and Elsevier Scopus.

The h-index has several weaknesses as well, many of which it shares with other citation-based indicators. The main ones include:

- It is dependent on field of research, database source, and career duration.
- The h-index lacks sensitivity to changes in performance; it never decreases and is only weakly sensitive to the number of citations.
- Self-citations and co-authors can positively influence its value.
- It allows scientists to rest on their laurels, since the number of citations may increase even if no new papers are published.
- It is only useful for comparing the better scientists or groups in a field. It does not differentiate between average ones.
- It is difficult to collect complete data for the determination of the h-index.
- The value of the h-index is always an integer, which results in too many h-indices of the same value. This makes it more difficult to distinguish between the achievements of scientists or aggregates with the same score.

Of the strengths listed above, the simplicity of the h-index is its greatest strength; requisite data are easily obtained and values are easily computed. However, its insensitivity to changes in performance remains a pressing concern as its greatest weakness (Costas and Bordons, 2007). The value of the h-index changes very little even when there are significant changes in the number of publications or citations. Although robustness is listed as one of its advantages, it is also a disadvantage in that it underlines the h-index's insensitivity to change. This reason has lead to most of the proposed improvements to the h-index, particularly the introduction of the following h-type indices:

- the g-index (Egghe, 2006),
- the real-valued h-index, hr (Rousseau, 2006a),
- the R- and AR-indices (Jin, Liang, Rousseau, & Egghe, 2007),
- the pure h-index (Wan, Hua, & Rousseau, 2007),

- the rational h-index, hrat (Ruane and Tol, 2008),
- the dynamic h-index (Rousseau and Ye, 2008).

Nonetheless, the above indices retain most of the weaknesses, in addition to the strengths, of the h-index itself. Is it possible to design new h-mixed indices that retain the strengths and overcome the weaknesses of the h-index? This is a valuable topic for studies, because such indices would provide a better and more accurate tool for academic assessment. Since the pair h and AR (Jin et al., 2007) is neither a simple nor single index and incorporates only limited academic information, we introduce simple and single h-mixed indices as improvements to the h-index based on the criteria discussed above, h-index and CPP, from which more useful academic information can be derived.

2. Methodology

Method

The new h-mixed synthetic indices seek to achieve both simplicity and sensitivity. They are based on the h-index and CPP, as the h-index and CPP are the simplest available indicators that combine publication output (linking to quantity) and citation impact (linking to quality).

Considering that CPP is meaningful for low publication output with high citations at any time and h-index balances both publication output and citation impact, h×CPP can be advanced as a new synthetic index . As the synthetic index h×CPP may result in large values, particularly for aggregates, instead, its logarithm can be used (Acs, Anselin, & Varga, 2002). The logarithm, however, may result in measurements too small to differentiate easily between values, so it is proposed to multiply the obtained result by 100 to create a new h-mixed synthetic index S, where S stands for synthesis and h×CPP>0:

$$S=100\times 1\mathrm{g}(h\times CPP) \qquad (1)$$

For convenience of applications, we use the base 10 in computation. By combining h and CPP, the S index retains most of their strengths and improves on some of the weaknesses of a single index, like the tendency of the h-index to only increase and both h and CPP's lack of sensitivity.

The total citations of the Hirsch core (Rousseau, 2006b), C_h, is also a useful parameter for distinguishing between two h-indices of the same value—the higher the value of $C_{h,}$ the greater the impact. The R-index is the square root of C_h and can be applied as a valuable parameter for measuring citations in the Hirsch core. Thus, another new h-mixed synthetic index T can be created by introducing R into the equation for S, where T stands for triad synthesis and R×h×CPP>0:

$$T=100\times 1g(R\times h\times CPP) \qquad (2)$$

S and T can be easily computed with data from the ISI Web of Science database, though the process of calculating C_h involves an added level of difficulty.

Since the logarithms are rather small, the S and T are multiplied by 100 to raise the value, and the values can then be stratified at intervals of 100: <100, 100-200, 200-300, 300-400, 400-500 and so on. Each interval of 100 marks a different level of academic achievement, where higher values of S and T correspond to greater levels of academic achievement, while S<100 or T<100 indicates poor level. As we set 100 as a multiplier in S and T, the 100 and its integral times become natural limit for differentiating various levels. 100 is just a boundary to indicate good (h×CPP≥10 for S and R×h×CPP≥10 for T) or poor (h×CPP<10 for S and R×h×CPP<10 for T). The poor level setting in S and T indicates the special comparable situation, which never shows in past indicators.

The two h-mixed synthetic indices are referable indicators at all levels and can be applied at any level of aggregation, including journal, research group, institution, and even country. Thus, S and T provide improved but still simple tools for academic assessment and are particularly effective at levels of aggregation.

Data

In order to provide practical examples, the synthetic indices S and T are applied below at the journal, institution, and author levels with data from ISI Web of Science (WoS) and at the assignee level with data from Derwent Innovations Index (DII). Data were collected for each group—journals, universities, authors, and assignees—for the period from 1998 to 2008 and are shown below in Table 1, in which P denotes publications, C citations, Ch citations in h-core and h indicates h-index. Here, different group represent different source, which are not comparable. The comparison is only done in same group. We only select a few samples as examples and selections are listed alphabetically within each group.

3. Results

The h-mixed synthetic indices S and T can be calculated according to the formulas (1) and (2), respectively, with the data from Table 1. The results are presented in Table 2 and are ranked by T, in which h and CPP are provided for comparison.

Table 2 demonstrates that the two h-mixed synthetic indices S and T are useful indicators for the overall measurement and ranking of academic bodies; accordingly, they are referable indices for the assessment of research performance.

Table 1. The sample data for the synthetic indices from ISI-WoS and DII(1998-2008)

Journal	**P**	**C**	**Ch**	**h**
Automatica	2,639	30,996	8,857	65
Economica	623	1,598	558	19
Lithos	1,436	14,400	3,887	47
Nature	30,602	1,527,176	432,289	486
Scientometrics	1,262	6,730	1,384	31
University	**P**	**C**	**Ch**	**h**
Cambridge	70,705	1,013,720	135,262	261
Heidelberg	32,605	401,676	61,754	169
Kyoto	60,735	723,093	83,650	217
Stanford	68,423	1,316,611	221,821	325
Zhejiang	27,224	109,893	8,724	69
Author	**P**	**C**	**Ch**	**h**
Bennett CL	390	18,054	15,647	47
Egghe L	100	509	274	11
Jones JDG	105	7,820	6,914	47
Kalnay E	57	2,204	2,001	15
Kroto HW	108	3,123	2,201	34
Assignee	**P**	**C**	**Ch**	**h**
AT&T	4,353	31,964	5,850	64
Boeing	4,762	11,170	1,305	29
Motorola	13,560	84,142	7,609	75
Siemens	47,952	93,058	3,798	50
Volkswagen	8,494	15,340	1,231	27

Data source: http://apps.isiknowledge.com, updated on Jan.1, 2009(Assignee on Jan.10, 2009)

In applications, S and T stand up as simple h-mixed synthetic indices for academic assessment that largely incorporate the strengths and overcome some of the weaknesses in single h or single CPP. Both indices can be conveniently applied to individual authors as well as to any level of aggregation, such as journals, research groups, institutions, and countries.

Table 2. The results of two h-mixed synthetic indices (1998-2008)

Journal	**CPP**	**h**	**S**	**T**
Nature	49.90	486	438.48	720.27
Automatica	11.75	65	288.28	485.64
Lithos	10.03	47	267.33	446.81
Scientometrics	5.333	31	221.83	378.89
Economica	2.565	19	168.78	306.12
University	**CPP**	**h**	**S**	**T**
Stanford	19.24	325	379.61	646.91
Cambridge	14.34	261	357.31	613.87
Kyoto	11.91	217	341.22	587.34
Heidelberg	12.32	169	331.85	571.38
Zhejiang	4.037	69	244.49	441.52
Author	**CPP**	**h**	**S**	**T**
Jones JDG	74.48	47	354.41	546.40
Bennett CL	46.29	47	333.76	543.48
Kroto HW	28.92	34	299.26	466.39
Kalnay E	38.67	15	276.34	441.41
Egghe L	5.09	11	174.81	296.70
Assignee	**CPP**	**h**	**S**	**T**
Motorola	6.205	75	266.78	460.85
AT&T	7.343	64	267.21	455.56
Siemens	1.941	50	198.69	377.67
Boeing	2.346	29	183.27	339.05
Volkswagen	1.806	27	168.81	323.32

4. Discussion

Improving on the function of the h-index, S and T can differentiate between achievements for entities with the same value h-index. The two synthetic indices also improve upon both h and CPP by being suitably sensitive to changes in publication and citation. Moreover, S and T combine the features of the h-core (total impact of h-core papers), the h-index (output and impact), and CPP (average impact of published papers) to produce valuable academic information. The rankings by T and h are in complete accordance, and there is only one instance where the rankings by S vary from T and h, which occurs in the assignee group. There is greater variation in the rankings by CPP but still largely in accordance with the other results.

While some h-type indices are being studied (Jin et al., 2007), other new indicators are simultaneously being introduced for academic assessment, such as the e-index (Zhang, 2009). However, we think that it is neither simple in data computations nor in practical applications.

The main advantages of S and T are their simplicity and sensitivity, for improving the h-index. They are among the simplest synthetic h-mixed indices proposed to date.

We recall the following formula for regarding the Hirsch core (Jin et al., 2007; Zhang, 2009):

$$R^2 = h^2 + e^2 = C_h = \sum_{j=1}^{h} C_j \geq g \cdot h \geq h^2 \quad (3)$$

If the citation rank-frequency function C(r) is thought of as a continuous function, the mathematical equation is:

$$C_h = \int_0^h C(r)dr \quad (4)$$

According to formulas (1) and (2), remembering lgX=clnX=clogX and c=lge=0.43429..., the resulting formulas are:

$$S=S(h,P,C)=c100(\log h+\log C-\log P) \quad (5)$$

and

$$T=T(h,e,P,C)=c100\,[\frac{1}{2}\log(h^2+e^2)h^2+\log(C/P)] \quad (6)$$

In the power law model, under the circumstance of Lotkaian informetrics was applied, Egghe-Rousseau formula of h-index (Egghe and Rousseau, 2006) had been derived as:

$$h=P^{1/\alpha} \quad (7)$$

where $\alpha>1$ is Lotka's exponent. Then, Eq. (5) becomes:

$$S=S(P,C)=c100(\frac{1-\alpha}{\alpha}\log P+\log C) \quad (8)$$

Eq. (8) means that S-index relates to only P and C in the power law model when $\alpha \neq 0$, and Eq. (6) means that T-index synthesizes and integrates the h-index, e-index, P, and C all together.

The formulas for both the S-index and the T-index contain the h-index and CPP, so they retain their main strength of both, simplicity, with combining sensibility. Thus, the S-index and the T-index are useful indicators for academic assessment.

5. Concluding remarks

The author advances two h-mixed synthetic indices empirically, S and T, for the purpose of research performance assessment, which in turn can serve as referable indicators for academic assessment. Both S and T maintain three obvious strengths:

- They are simple indices for which it is easy to collect data and to apply practically.
- They are sensitive to changes in academic performance by combining the h-index and CPP, since CPP fluctuates but the h-index only ever increases.
- They balance publication output and citation impact and can be applied to individual authors as well as to any level of aggregation.

They also retain two observations:

- They are field-dependent and database-dependent, similar to the h-index.
- They can be positively influenced by self-citations and by co-authors.

The h-mixed synthetic indices S combined two single indices (h and CPP) and T did three ones (R, h and CPP). They become overall referable indicators that measure both output and impact. They integrate the strengths of the h-index and CPP, to achieve simplicity and sensitivity to changes in performance. Opportunities exist for future studies to complement and improve upon this work and other already published works.

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References

Acs, Z. J., Anselin, L., & Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy, 31*(7), 1069-1085.

Costas, R., & Bordons, M. (2007). The h-index: Advantages, limitations and its relation with other bibliometric indicators at the micro level. *Journal of Informetrics, 1*(2), 193-203.

Döring, T. F. (2007). Quality evaluation needs some better quality tools. *Nature, 445*, 709.

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

Egghe, L. (2007). Dynamic h-index: The Hirsch index in function of time. *Journal of the American Society for Information Science and Technology, 58*(3), 452-454.

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

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

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

Jin, B., Liang, L., Rousseau, R., & Egghe, L. (2007), The R- and AR-indices: Complementing the h-index. *Chinese Science Bulletin, 52*(6), 855-863.

Moed, H. F., De Bruin, R. E., & Van Leeuwen, Th. N. (1995). New bibliometric tools for the assessment of national research performance: Database description, overview of indicators and first applications. *Scientometrics, 33*(3), 381-422.

Rousseau, R. (2006a). Simple models and the corresponding h- and g-index. Available at *E-LIS,* ID Code 6153.

Rousseau, R. (2006b). New developments related to the Hirsch index. *Science Focus*, *1*(4), 23-25. [text in Chinese]. An English translation is available at *E-LIS*, ID Code 6376.

Rousseau, R. (2008). Reflections on recent developments of the h-index and h-mixed indices. *COLLNET Journal of Scientometrics and Information Management, 2*(1), 1-8. see also *Proceedings of WIS 2008*, http://www.collnet.de/Berlin-2008/

Rousseau, R., & Ye, F. Y. (2008). A Proposal for a dynamic h-mixed Index. *Journal of the American Society for Information Science and Technology, 59*(11), 1853-1855.

Ruane, F. P., & Tol, R. S. J. (2008). Rational (successive) h-Indices: An application to economics in the Republic of Ireland. *Scientometric*s, *75*(2), 395-405.

Schubert, A., & Glänzel, W. (2007). A systematic analysis of Hirsch-mixed indices for journals. *Journal of Informetrics, 1*(2), 179-184.

Van Raan, A. F. J. (2005). Statistical properties of bibliometric indicators: Research group indicator distributions and correlations. *Journal of the American Society for Information Science and Technology, 57*(3), 408-430.

Vinkler, P. (2003), Relations of relative scientometric indicators. *Scientometrics*, 58(3), 687-694.

Wan, J., Hua, P., & Rousseau, R. (2007). The pure h-index: Calculating an author's h-index by taking co-authors into account. *COLLNET Journal of Scientometrics and Information Management, 1*(2), 1-5.

Ye, F. Y., & Rousseau, R. (2008). The power law model and total career h-index sequences. *Journal of Informetrics*, *2*(4), 288-297.

Zhang, C.-T. (2009). The e-index, complementing the h-index for excess citations. *PLoS ONE, 4*(5), e5429. doi:10.1371/journal.pone.0005429

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