Is Journal Impact Factor a Good Measure of Research Merit?

S. K. MISHRA

Introduction

On September 23rd 2009 the University Grants Commission notified its Regulation on "Minimum Qualifications for Appointment of Teachers and other Academic Staff in Universities and Colleges and Measures for the Maintenance of Standards in Higher Education". Accordingly, publication of research papers/articles in reputed journals has become an important factor in assessment of the academic performance of teachers in colleges and universities in India. One of the measures of reputation and academic standard of a journal is the so-called 'Impact Factor', which, with some qualifications, is the average number of citations for papers published in a particular journal. It is obtained as the ratio of the total number of citations received by the papers published in the journal to the number of papers published in the journal. The impact factor was devised by Eugene Garfield. Garfield is the founder of the Institute for Scientific Information (ISI), which is now part of Thomson Reuters. Impact factors are calculated annually for those journals that are indexed in Thomson Reuter's *Journal Citation Reports*. However, *Journal Citation Reports* covers science subjects more exhaustively and includes only a few social science journals. Therefore, in social sciences, other organizations are doing this job. For example, RePEc does the job of computing the impact factor of journals in Economics.

The computation of impact factor uses a simple formula. As described in the *Wikipedia*, in a given year, the impact factor of a journal is the average number of citations to those papers that were published during the two preceding years. For example, the 2007 impact factor of a journal would be calculated as follows:

A = the number of times articles published in 2005 and 2006 were cited by indexed journals during 2007

Professor S. K. Mishra teaches Economics at North-Eastern Hill University. He can be contacted at mishrasknehu@yahoo.com

B = the total number of "citable items" published in 2005 and 2006. ("Citable items" are usually articles, reviews, proceedings, or notes; not editorials or Letters-to-the-Editor.)

2007 impact factor = A/B

Note that 2007 impact factors are actually published in 2008; it cannot be calculated until all of the 2007 publications have been received by the indexing agency.

The UGC Regulations assign different levels of importance to the impact factors in natural sciences/engineering and humanities/arts/social science streams of higher education. For this purpose, they classify Engineering, Agriculture, Veterinary Science, Sciences and Medical Sciences in one category and Languages, Arts, Humanities, Social Sciences, Library, Physical Education, and Management in the other category. Table 1 shows how the UGC Regulations assign importance to impact factors in these two categories.

Table 1: Relative Weightage assigned to Impact Factors (IF) in the Different Categories of Disciplines

Engineering/Agriculture/Veterinary Science/ Sciences / Medical Sciences [The Sciences Category]	**Languages, Arts/ Library/ Humanities/ Social Sciences/ Physical Education/ Management [The Non-Sciences Category]**	**Max. points for university and college teacher position**
Refereed and indexed journals with impact factor 0.0 but less than 1.0	Refereed journals which are *not indexed* and thus have no impact factor	15 per publication
Refereed journals with impact factor 1.0 and below 2.0	Refereed journals which are indexed publications with impact factor less than one	20 per publication
Refereed journals with impact factor 2.1 and below 5.0	Refereed journals with impact factor 1.0 and below 2.0	30 per publication
Refereed journals with impact factor 5.1 and below 10.0	Refereed journals with impact factor 2.0 and below 5.0	40 per publication
Vernacular & Indian language journals in all disciplines without any impact factors included in the list of journals prepared by UGC and hosted in its website	Vernacular & Indian language journals in all disciplines without any impact factors included in the list of journals prepared by UGC and hosted in its website	10 per Publication
Non impact factor national level research papers in non-refereed/ journals but having ISBN/ISSN numbers and the list of journals prepared by UGC and hosted in its website.	National level research papers in non-refereed/non journals but having ISBN/ISSN numbers and the list of journals prepared by UGC and hosted in its website.	10 per publication
Full papers in conference proceedings, etc. (Abstracts not to be included)	Full papers in conference proceedings, etc. (Abstracts not to be included)	10 per publication

Note: Class intervals of **IF** as given in the UGC Regulations are faulty. What if the **IF** lies in the interval [2, 2.1)?

On this account several questions can be and have been raised from different corners. Some view it as a discrimination against 'sciences' and favour to non-sciences (without any disparaging connotation, of course). Others (e.g. Seglen 1997, Krell 2002) think that even within the 'sciences' there is so much of difference in the journal impact factors that no single yardstick can be used to assign importance to them. In support of their argument they point out that there are few journals in Mathematics that have an impact factor above 5.0 while such journals abound in life sciences (HTST 2004, International Mathematical Union 2007). There are still others (e.g. Wagner 2009) who think that instead of using the crude journal impact factor for assessment of importance one should use the 'normalized' impact factor and possibly, the average impact factor (computed over, say, five best journals in the discipline) may be considered as 100.0 and other journal impact factors (in the discipline) should be normalized with respect to that such that all journals in the discipline score between 0 and 100.0. And lastly, there are many (e.g. Seglen 1997, Hirsch 2005, Oh and Lim 2009) who believe that the journal impact factor, as it has been defined, is a surely misleading indicator of academic importance especially when the inter-disciplinary comparisons are made.

What Statistics Says

We have collected some data on the journal impact factors for two points in time; for the year 1994 (source: http://www.mkk.szie.hu/~fulop/Res/If/If.htm) and for the year 2006 (source: http://www.icast.org.in/Impact/subject2006.html). We have been constrained by unavailability of data especially in the 'non-sciences' and therefore we have used the data for the year 2002 (Source: http://www.staff.city.ac.uk/~sj361/here_you_can_see_an_excel_spread.htm). For Economics, the *Internet Documents in Economics Access Service* (IDEAS) journal impact factors are available and are updated regularly (http://ideas.repec.org/top/top.journals.simple.html). We assume some sort of stability in the journal impact factor (without which assumption it loses all its value) and thus, in spite of the obvious limitations, we venture upon comparing them.

Methodologically, we have included only those journals that have positive (larger than zero) impact factor. The journals that are indexed but have not yet gained any impact factor are thus excluded from our analysis. Then we have used mean and standard deviation of the ($\log_{10}$ transformation of) journal impact factors in different discipline groups and their frequency

distribution to arrive at the conclusions. We have also computed the median and the skewness of the distributions. The most up-to-date (for the year 2006 for sciences and engineering, and the year 2002 for Psychology and social sciences) information on the impact factors reveal that the frequency distributions in the subject groups of engineering, social sciences and Psychology, the mean and the median are both negative. In particular, engineering and social sciences have quite low mean impact factor. Distribution of impact factor in these subject groups exhibit negative skewness too. On the other hand, in case of Biology, Chemistry and Physics, the mean and the median are both positive. However, the skewness is positive for Physics alone (Table 2). In particular, skewness in Chemistry and Physics is mild. Distributions are presented in the graphs presented in Fig.1 and Fig.2. It may be noted that major characteristics of impact factor distributions have remained more or less constant over the years (1994 and 2002).

Table 2: Statistical Description of Journal Impact Factor Distribution in Different Subject Groups-2006

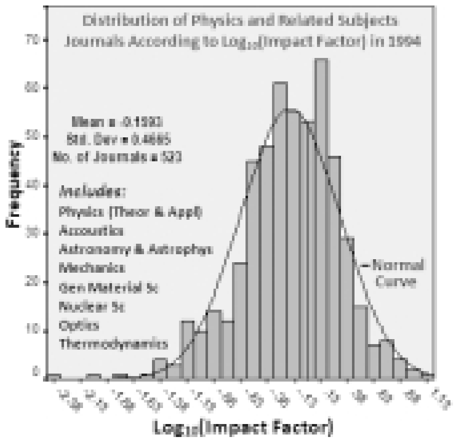
Subject Group	No. of Journals	Mean	Median	Minimum	Maximum	Std.Dev.	SEE(Mean)	Skewness	SEE(Skew)
Biology	1043	0.2484	0.3300	-1.4400	1.8000	0.4336	0.0134	-0.3111	0.0757
Chemistry	433	0.1837	0.1000	-1.2900	1.4200	0.4266	0.0205	-0.0321	0.1173
Engineering	706	-0.2477	-0.1900	-1.0000	1.0200	0.4565	0.0172	-1.0639	0.0920
Physics	298	0.0442	0.0900	-1.3600	1.5251	0.3966	0.0231	0.2372	0.1421
Psychology	421	-0.0813	-0.0700	-1.5100	0.9400	0.3835	0.0187	-0.3145	0.1190
Social Sc.	1301	-0.2112	-0.2100	-1.9600	1.0700	0.4166	0.0115	-0.4901	0.0678

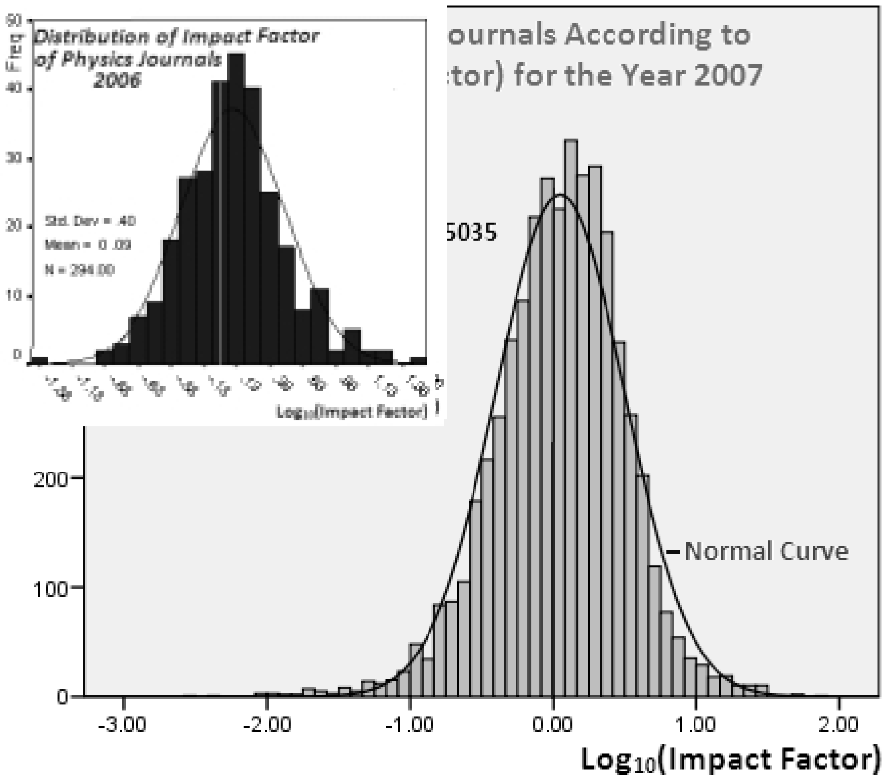
Distribution of Logarithms of Impact Factors is Pearsonian of Type-IV

Mansilla *et al*. (2007) observe that journal impact factors (IF), irrespective of the discipline, exhibit their adherence to a specified rank-size rule. Egghe (2009) makes an attempt to give a theoretical explanation for the IF rank-order distributions observed by Mansilla *et al* (2007). Waltman and Eck (2009), while concluding that Egghe's analysis relies on the unrealistic assumption that the articles published in a journal can be regarded as a random sample from the population of all articles published in a field (and Egghe's analysis is not in agreement with empirical data and hence he does not give a satisfactory explanation for IF rank-order distributions), observe:

> Egghe interprets the IF of a journal as the average of a number of independent and identically distributed random variables. Each random variable represents the number of citations of one of the articles published in the journal. Using the central limit theorem, Egghe's interpretation implies that the IF of a journal is a random variable that is (approximately) normally distributed. Egghe also makes the

assumption that for a given scientific field *each journal in this field can be considered as a random sample in the total population of all articles in the field*. This assumption has the implication that the IFs of all journals in a field follow the same normal distribution. (emphasis in original)





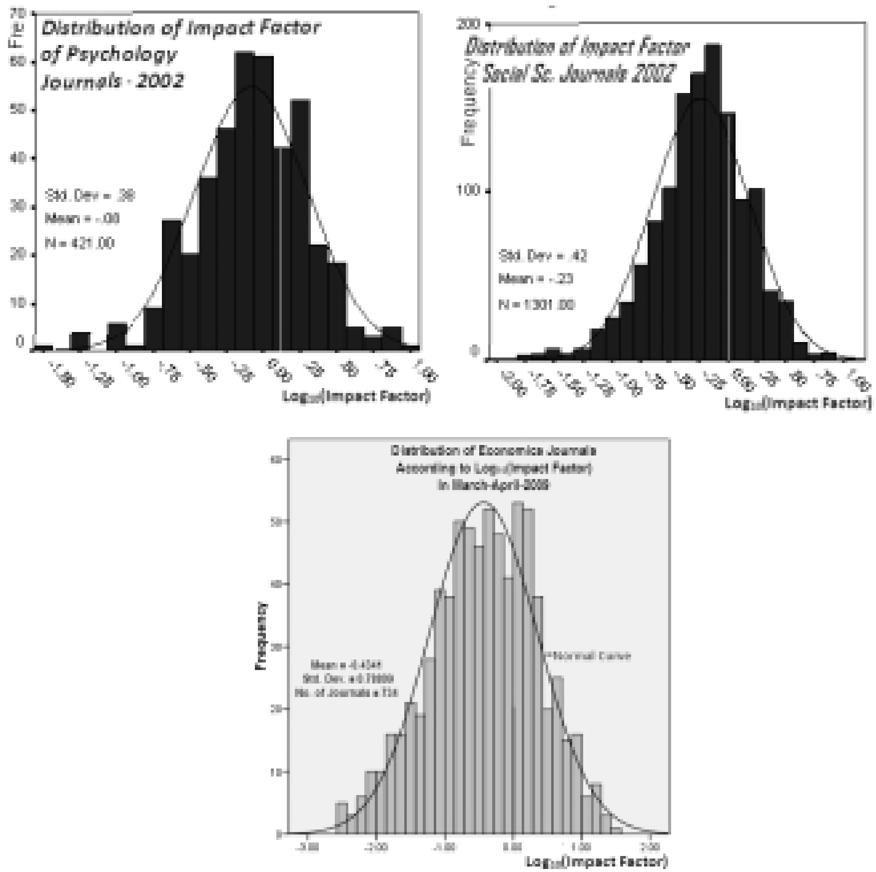


Fig.2. Statistical Distribution of Journal Factors in Various Subject Groups in 2002/2006

Table 3: Estimated Coefficients and Measures of Pearson Distribution fitted to IF Data Factor Data

Subject-Group(year)	N	b_0	b_1	b_2	Root of $f(x)$	Skewness	Kurtosis	$Pearson-\kappa$	Type
Biology(2006)	1043	-0.13245	0.04095	-0.09840	$0.2081 \pm 1.1414i$	-0.31155	1.33611	0.03216	IV
Chemistry(2006)	433	-0.18150	0.00710	-0.00011	$32.6043 \pm 24.5635i$	-0.03335	0.00232	0.63792	IV
Engineering (2006)	706	-0.15391	0.15781	-0.08690	$0.9080 \pm -0.9730i$	-1.06030	2.86756	0.46550	IV
Physics(2006)	294	-0.11677	-0.03084	-0.08505	$-0.1811 \pm -1.1576i$	0.23610	0.98391	0.02394	IV
Psychology(2002)	421	-0.12049	0.04583	-0.05942	$0.3856 \pm -1.3707i$	-0.31400	0.66766	0.07333	IV
Social Sc.(2002)	1301	-0.13851	0.07492	-0.06681	$0.5608 \pm -1.3262i$	-0.49133	1.00031	0.15166	IV

Note: Minor variations in some statistics reported in Tables 2 and 3 are due to accuracy used in computation.

These observations suggest that we should carry out further investigations into the statistical distribution of the IFs in different disciplines. In this regard we think it appropriate to fit Pearson's Distribution to the IF data for different subject groups.

It is well-known that the Pearson's distributions can be specified by the first four moments of a given set of data, i.e., coefficients of the equation $f(x) = b_2x^2 + b_1x + b_0$ are determined in terms of mean, variance, skewness and kurtosis (Gupta and Kapoor 1970: 543-52, also see *Wikipedia*: "Pearson Distribution"). The values of b_0, b_1 and b_2 determine the shape of empirical distribution. The details of all these statistics are given in Table 2 and Table 3. It may be noted that in all subject groups, the distribution of IF exhibit Pearson's Type-IV distribution with varied skewness and kurtosis. These empirical evidences support the criticism of Egghe's arguments made by Waltman and Eck (2009) and thus we cannot assert that the distributions of journal impact factors across the discipline groups are more or less identical or normal. Thus, the comparison of journal impact factors across the disciplines would be absolutely misplaced and misleading.

Does the Impact Factor Provide an Accurate Measure of a Journal's Importance?

In counting citations, only papers published in the past two years are considered. In fact, many papers are appreciated after several years of their publication and then referred while many other papers continue influencing others' research for much longer period. Also, items such as news articles and editorials that are the regular features of some journals are not counted in the denominator of the impact factor, but citations to those news articles may be included in the numerator, inflating the impact factor of journals that publish such articles. Due to these and several other limitations, the impact factors may only poorly measure the quality of a journal (Kurmis 2003).

Review articles are often much more highly cited than the average original research paper, so the impact factor of review journals can be quite high. In some fields, there have been reports (Hemmingsson *et al*. 2002) of journals that have manipulated their impact factors by such tactics as adding news articles, accepting papers preferentially that are likely to raise the journal's impact factor, or even asking authors to add citations to other articles in the journal.

Should the Journal Impact Factor be used for Evaluation of an Individual Publication or Researcher?

As pointed out in the *Wikipedia*, "the impact factor is often misused to evaluate the importance of an individual publication or evaluate an individual researcher (Seglen 1997). This does not work well since a small number of publications are cited much more than the majority. For example, about 90 percent of *Nature*'s 2004 impact factor was based on only a quarter of its publications, and thus the importance of any one publication will be different and on the average less than the overall number (Editorial: *Nature* 2005). The impact factor, however, averages over all articles and thus underestimates the citations of the most cited articles while exaggerating the number of citations of the majority of articles. Consequently, the Higher Education Funding Council for England was urged by the House of Commons Science and Technology Select Committee to remind Research Assessment Exercise panels that they are obliged to assess the quality of the content of individual articles, not the reputation of the journal in which they are published. To quote:

> As is the case with any process, peer review is not an infallible system and to a large extent depends on the integrity and competence of the people involved and the degree of editorial oversight and quality assurance of the peer review process itself. Nonetheless we are satisfied that publishers are taking reasonable measures to maintain high standards of peer review…The perception that the RAE (Research Assessment Exercise) rewards publication in journals with high impact factors is affecting decisions made by authors about where to publish. We urge HEFCE to remind RAE panels that they are obliged to assess the quality of the content of individual articles, not the reputation of the journal in which they are published. (HTST 2004).

Even the scholars in medical sciences (that have a very high IF) question the validity of the journal impact factor as a measure of relevance of individual articles or scholars (Oh and Lim 2009). Some scholars hold that the rise of the journal impact factor is a result of the perceived value of quantification measures in the contemporary society and the restructuring of capitalism. A key implication of this acceptance is an increase in global academic dependency (Luyt 2009). It may be noted that in India we have hardly any journal that has an impact factor greater than one. For example, even the IDEAS (which is especially indexing Economics and some Statistics journals) index only six Indian journals in Economics and the highest IF is less than one. Interestingly, the *Indian Economic Review* of the reputed Department of Economics, Delhi School of Economics has an impact factor of only about 0.24. For physical and life sciences journals too, the conditions are not much better.

Use of journal impact factor for academic evaluation of individuals is widely deplored (Russell and Singh 2009). If journal impact factor is used to assess the academic performance of individuals (for the purpose of selection, promotion, etc) and it is not borne in mind that due to vast differences in the nature of distribution of impact factors across the disciplines they are not justifiably comparable, a below average scholar in the one discipline will rank higher and will be honoured (and benefitted) more than a better scholar in some other discipline. The International Council of Industrial and Applied Mathematics (ICIAM), the Institute of Mathematical Statistics (IMS), and the International Mathematical Union (IMU) – institutions representing the world wide communities of mathematicians and statisticians – are troubled by the possible misuse of mathematical concepts or statistical indicators such as the journal impact factor (International Mathematical Union 2007). Further, even in the university departments there are specializations with low impact factor journals and other specializations with very high impact factor journals. But the teachers/researchers of different specializations in the departments compete with each other for promotion. For example, in the life sciences, taxonomy is one such specialization. Its long-term relevance, few specialists and lack of core journals put it outside ISI criteria (Krell 2002). Will the researchers with an unfortunate specialization (wherein the journal impact factor is subdued) receive justice on such criteria? The answer is clearly in negative.

Measuring Quality, Productivity and Academic Impact of Individual Scholars

Once we question the use of IF for evaluation of an individual scholar's research quality, his/her productivity and the academic impact made by his/

her research work, we must propose some other measure that may be a better substitute of the journal impact factor. Such an index is the h-index (Hirsch 2005) proposed by Jorge E. Hirsch, a physicist at the University of California, San Diego.

The Hirsch Index (or *h*-index) is an index that attempts to measure both the scientific productivity and the scientific impact of a scientist. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other researchers' publications. As Hirsch defines it: a scientist has index *h* if *h* of his or her *Np* papers (that is, the total number of papers written by him/her) have *at least h* citations each and the other (*Np - h*) papers have *at most h* citations each. To illustrate, let a scientist be an author of a total of 20 (=Np) papers which arranged (in a descending order) according to the citations received by them makes Table 4 presented below:

Fig.3. A schematic presentation of h-index

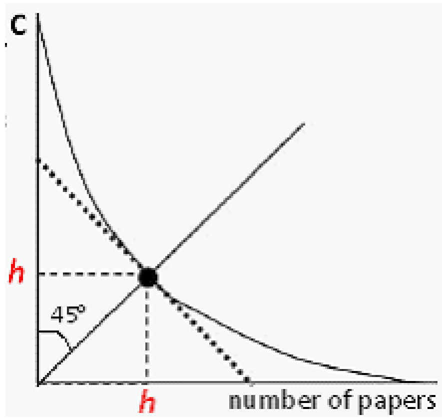


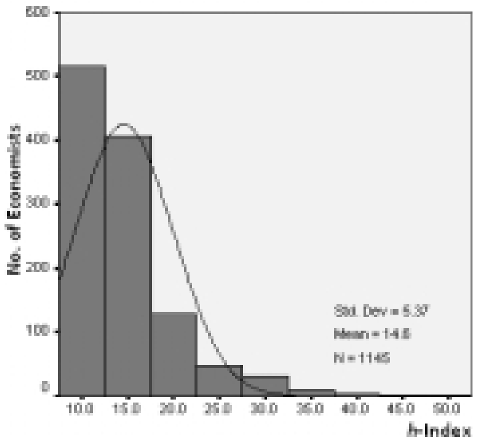
Table 4. An Illustrative Example of an Author's Papers arranged according to the Number of Citations Received

Paper no (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Citations (c)	186	171	92	90	90	48	26	16	7	6	6	5	4	4	4	3	3	1	1	0

It is readily seen (in Table 4) that up to the 8^{th} one, all papers receive citations greater than 8. However the 9^{th} paper of the author receives only 7 citations. Thus, the author's h-index is 8. In Fig. 3 we present a schematic curve of number of citations versus paper number, with papers numbered in order of decreasing citations. The intersection of the 45° line with the curve gives *h*. The total number of citations is the area under the curve.

The Google Scholar (http://www.scholar.google.com) can be conveniently used to obtain the *h*-index of a scholar. Harzing (2008) argues that the Google Scholar h-index might provide a more accurate and comprehensive measure of journal impact and at the very least should be considered as a supplement to ISI-based impact analyses, which implies that the Google Scholar database is more comprehensive. Once the name of a scholar is fed into the search window and the Google Scholar is asked to search, the list of the scholar's publication/paper (it may run in several pages) appears with the data on the number of citations received by the publication/ paper. Fortunately, in most cases (barring a few cases where the scholar may not be the first author) we obtain the list arranged in a descending order of the citation received by the publications/papers. One has to go down the list until the serial number of the paper becomes larger than the number of citations received. Nevertheless, care must be taken to see that the list may be a mixture of the publications of the authors with the same name, or the same author may on one occasion use his/her initials and the full name or the first name only at others. With these precautions, the h-index of an author/scholar may easily be determined.

Distribution of h-Index of Best 5% Economists in the World



The Hirsch Index as a measure of individual author's productivity and academic influence has been widely accepted (see Ball 2005). Schaefer (2009) obtained the ranking of 572 living chemists in the world who have the h-index 50 or larger, displayed by *Chemistry World* online. *The RePEc* (2009) provides the h-index of top 5% economists on its data-base, having over 21 thousand authors. Palsberg (2009) provides the h-index of scholars in Computer Science. There are a number of programmes that may be used to compute h-index (see *Wikipedia*: Computing the h-Index), including scHolar index and Harzing's publish or perish. However, in the present author's experience, these online software programmes do not work so often and it is better to use the Google Scholar manually.

Hirsch, in his paper, suggested that "for faculty at major research universities, *h* 12 might be a typical value for advancement to tenure (associate professor) and that *h*18 might be a typical value for advancement to full professor. Fellowship in the American Physical Society might occur typically for *h*15–20. Membership in the National Academy of Sciences of

the United States of America may typically be associated with *h*45 and higher, except in exceptional circumstances". Hirsch also noted that "results confirm that *h* indices in biological sciences tend to be higher than in physics; however, they also indicate that the difference appears to be much higher at the high end than on average". Thus, h-Index also should be used cautiously while making interdisciplinary comparisons or even inter-specialization comparisons.

Tol (2008) notes that "the main shortcoming of the *h*-index … is that it ignores the number of citations in excess of *h*. Egghe (2006) and Jin (2006) therefore introduce the *g*-index: Like the *h*-index, the *g*-index only counts papers of a minimum quality. A higher *g*-index means more and better papers. Unlike the *h*-index, the *g*-index also increases with the number of citations over the threshold". Therefore, Tol proposed a successive *g*-index and a rational *g*-index (to increase discrimination of Hirsch's *h*-index), which we will call Tol's g-index. The Google Scholar can be effectively used for computing Tol's g-index as well.

Concluding Remarks

We began this paper by raising this question – is publication in journals with recommended impact factor as a measure of quality of scholar for the purpose of appointments and promotion to different positions in the academic institutions just or appropriate? We find that use of the journal impact factor for the said purpose is inappropriate. Instead, a measure such as h-index which quantifies the quality as well as productivity of an individual author/ scholar is more appropriate than the journal impact factor. The h-index may be fine-tuned and the g-index or Tol's index may be used. Nevertheless, even the h-index and Tol's index would not be appropriate to the purpose of inter-disciplinary or inter-specialization comparisons. A more informed and balanced judgment of the expert committee for selection, appointment and promotion purposes will continue to be extremely important.

References

Ball, P. 2005. Index aims for fair ranking of scientists. *Nature*, 436, 900 (18 August 2005) doi:10.1038/436900a; http://www.nature.com/nature/journal/v436/n7053/full/436900a.html.

Schaefer, H. 2009. H-index Ranking of Living Chemists. *Chemistry World*, August 20, 2009, at www.rsc.org/chemistryworld/News/2007/April/23040701.asp.

Editorial: *Nature*. 2005. Not-so-deep Impact. *Nature,* 435 (7045): 1003–4. doi:10.1038/ 4351003a. PMID 15973362.

Egghe, L. 2006. Theory and Practice of the g-Index. *Scientometrics*, 69 (1): 131-52.

Egghe, L. 2009. Mathematical Derivation of the Impact Factor Distribution. *Journal of Informetrics*, 3(4): 290-95.

Garfield, E. 2006. The History and Meaning of the Journal Impact Factor. *The Journal of the American Medical Association*, 295(1): 90-93.

Gupta, S.C. and V. K. Kapoor. 1970. *Fundamentals of Mathematical Statistics.* New Delhi: Sultan Chand & Sons.

Harzing, A. and R. van der Val. 2008. Comparing the Google Scholar h-index with the ISI Journal Impact Factor. http://www.harzing.com/h_indexjournals.htm.

HCST. 2004. House of Commons - Science and Technology - Tenth Report. 2004-07-07 http://www.publications.parliament.uk/pa/cm200304/cmselect/cmsctech/399/39912.htm.

Hemmingsson, A., T. Mygind, A. Skjennald and Edgren J. Johan. 2002. Manipulation of Impact Factors by Editors of Scientific Journals. *American Journal of Roentgenology,* 178: 767. http://www.ajronline.org/cgi/content/full/178/3/767.

Hirsch, J.E. 2005. An Index to Quantify an Individual's Scientific Research Output. *PNAS*, November 15, 2005 , 102(46): 16569–72.

International Mathematical Union. 2007. Joint ICIAM/IMS/IMU-Committee on Quantitative Assessment of Research: Terms of Reference; http://www.ams.org/ams/impact-factor.pdf; also see http://emis.zblmath.fiz-karlsruhe.de/mirror/IMU/Publications/News.html.

Jin, B. 2006. H-Index: An Evaluation Indicator Proposed by Scientist. *Science Focus (Chinese)*, 1(1): 8-9.

Krell, F.T. 2002. Why impact factors don't work for taxonomy. *Nature,* 415, 957; doi:10.1038/415957a http://www.nature.com/nature/journal/v415/n6875/full/415957a. Html.

Kurmis, A. P. 2003. Understanding the Limitations of the Journal Impact Factor. *J. of Bone and Joint Surgery (American),* 85:2449-54; www.ejbjs.org/cgi/content/abstract/85/12/2449.

Luyt, B. 2009. The political economy of the journal impact factor. http://www.cais-acsi.ca/proceedings/2009/Luyt_2009.pdf.

Mansilla, R., E. Köppen, G. Cocho and P. Miramontes. 2007. On the behavior of journal impact factor rank-order distribution. *Journal of Informetrics*, 1(2): 155–60.

Oh, H.C. and J.F.Y. Lim. 2009. Is the journal impact factor a valid indicator of scientific value? *Singapore Med. Journal***,** 50(8): 749-51.

Palsberg, J. 2009. The h Index for Computer Science. University of California, Los Angeles http://www.cs.ucla.edu/~palsberg/h-number.html.

Russell, R. and D. Singh. 2009. Impact factor and its role in academic promotion. *International Journal of COPD,* 4: 265-66. http://www.dovepress.com/impact-factor-and-its-role-in-academic-promotion-peer-reviewed-article.

Seglen, P.O. 1997. Why the impact factor of journals should not be used for evaluating research. *BMJ (British Medical Journal),* 314 (7079): 498–502. http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=2126010&blobtype=pdf.

Tol, R.S.J. 2008. A rational, successive g-index applied to economics departments in Ireland. *Journal of Informetrics*, 2(2): 149-55.

Wagner, A.B. 2009. Percentile-Based Journal Impact Factors: A Neglected Collection Development Metric. http://www.istl.org/09-spring/refereed1.html.

Waltman, L. and N.J.V. Eck. 2009. Some comments on Egghe's derivation of the impact factor distribution. *Journal of Informetrics*, 3(4): 363-66. http://*papers.ssrn.com/sol3/papers.cfm?abstract_id=1365059*.