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Rank-Normalized Impact Factor: A Way to Compare Journal Performance Across Subject Categories

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It is well known that uninformed science administrators often use ISI's journal impact factors without taking into account the inherent citation characteristics of individual scientific disciplines. A rank normalized impact factor (rnIF) is proposed which involves use of order statistics for the complete set of journals within each *JCR* category. We believe the normalization procedure provides reliable and easily interpretable values. For any journal j, its rnIF is designated as $rnIF_j$ and equals $(K - R_j + 1)/K$, where R_j is the descending rank of journal j in its *JCR* category and K is the number of journals in the category. Note: *JCR* impact factor listings are published in descending order. The proposed rnIF is compared with normalized impact factors proposed by earlier authors. The efficacy of the rnIF is illustrated in the cases of seven highly-cited scientists, one each from seven different fields.

Introduction

Journal impact factors have been the subject of considerable controversy ever since their introduction in the seventies. At first, the *Journal Citation Reports* (*JCR*) appeared as the last volume of the *Science Citation Index* in 1975. About 1990, it became an independent serial in microfiche. Later it was published on CD-ROM, and now is available on-line via the web. At first, the *JCR* was used primarily by libraries to make purchasing and weeding decisions. In the eighties, impact factors began to be used by administrators in evaluating grant applications and for tenure. While cumulated citation data on the earlier work of scientists could be obtained from the *Science Citation Index* (*SCI*), the evaluation of papers of recent vintage could not be judged, especially in fields with relatively long half lives. Consequently, the impact factor (IF) became a surrogate for the expected citation frequency for recently published papers. (Most administrators overlooked the fact that a small percentage of recent papers were indeed "hot" and even one to two years of citation data were predictive of future performance.)

In recent years, *Nature* has made the impact factor a regular matter of controversy. Quite recently there has been a heated discussion of the journal IF in the evaluation of individual scientists and laboratories. In some countries grant application reviews routinely involve the ISI journal IF in considering the applicant's publications (Adam, 2002; Lawrence, 2002; Georgiev, 2003). This practice is often justifiably criticized (Lawrence, 2002; Amin & Mabe, 2002; Warner, 2003).

The dangers of surrogate use have been criticized. For example, Seglen, demonstrating the skewed distribution of citations to papers, strongly recommended against this practice (Seglen, 1997). Nevertheless, the practice not only continues but has expanded. The use of impact factors within subject categories might be justified since the changes in rank over the years is not significant (Garfield 1998). But the egregious and promiscuous use of IF across disciplines is irresponsible. It should be obvious to even the unsophisticated user of *JCR*, that comparisons across disciplines are invidious. Nevertheless, we find uninformed administrators still using impact factors to compare molecular biologists with physiologists or to compare physicists with taxonomists. For this reason, a number of authors have developed normalization procedures that would permit administrators to even the playing field. While these normalization procedures are important even for examining the within-category *JCR* rankings, our main purpose here is to provide a rank normalization procedure for cross-category comparisons.

To overcome the problem of comparing IF across different specialties, Sen and Marshakova-Shaikevich have suggested using a normalized IF (Sen, 1982; Marshakova-Shaikevich, 1996). However, these normalizations are not quite satisfactory, as they involve either the maximal IF or a few of the highest IFs in each specialty. These "champion" values are not always characteristic of IF values of the majority of journals within the specialty and thus introduce fortuitous elements in the normalized IF.

We suggest a rank normalized IF which involves order statistics for the whole set of journals in a specialty. This normalization procedure, which is similar to percentile ranking, provides more reliable and easily interpretable values we call rank-normalized impact factors or (rnIF).

We test the effectiveness of our approach by computing rnIF for the most-cited authors in seven different fields. The information on these highly-cited scientists is taken from a free online database of the Institute for Scientific Information (ISI) (www.isinet.com), posted on the web at www.isihighlycited.com . Further, we compare the rnIF values with the *JCR* IF as well as normalized IFs, using the methods of S. K. Sen and Irina Marshakova-Shaikevich. We demonstrate that our rnIF for the journals in which the authors' papers were published are indeed high and similar while the other normalizations produce disparate results. Our main reason for using a group of highly-cited authors is to demonstrate that the rnIF for the journals in which they publish are quite similar whereas *JCR* IFs for this small group vary quite widely.

Normalized Impact Factors

For any journal j the rank normalized impact factor $rnIF_j = (K - R_j + 1)/K$, where R_j is the *JCR* rank of journal j and K is the number of journals in its category. Keep in mind that within each *JCR* category journals are always displayed in descending order. For example, the journal *Genetics* is the 17th from the top (when sorted by descending IF) in the *JCR* category for *Genetics & Heredity*. In 2000, this category contained 114 journals. Thus, $rnIF_{Genetics} = (114-17+1)/114 = 0.860$. The value of rnIF is very easy to interpret: if a journal j has $rnIF_j = X$ it means that 100% x (1 – X) of the journals in its *JCR* category have higher IF values. So, for the journal *Genetics* 14% of the journals in its category have higher IFs. Under the suggested normalization the top journals in each subject category have rnIF equal to 1.0 and the median journals will have rnIF close to 0.5. When a journal is assigned by the *JCR* to two or more different categories we average the rnIF values.

Sen, henceforth designated S, suggested the following normalization procedure: $SnIF_j = IF_j/maxIF \times 10$, where IF_j is the *JCR* IF for journal j, maxIF is the maximal IF value for the *JCR* category to which journal j is assigned. Further we have slightly modified this value by multiplying the ratio by 100 rather than 10. Then Sen's value is the percentage that IF_j constitutes from the top IF value in the *JCR* subject category. Sen's approach was used to analyze Indian and Chinese literature on laser physics (Carg, Padhi, 1999; Carg, 2001).

Marshakova-Shaikevich, henceforth designated M, suggested a similar normalization: $MnIF = IF_j/ av5maxIF \times 100$, where av5maxIF is the weighted average of the top five IF values in the *JCR* subject category, to which the journal j pertains. The weighting is done by the number of papers published in each of the five journals during the two years preceding the current year. Marshakova-Shaikevich's normalized IF was used in the analysis of Russian literature (Marshakova-Shaikevich, 2002, 2003). M is the Marshakova of co-citation fame.

Table 1 presents the IF, SnIF, MnIF and rnIF for journals in five *JCR* categories. The names of the journals are given in Table 2. Data for six journals in each category are given: for 5 journals with the highest IFs and for the median one. It is clearly seen that IF values vary greatly among the disciplines. There is almost an eighteen-fold difference between IFs for the top journals in the biochemistry/molecular biology category (top IF = 43.4) and the agronomy category (top IF = 2.4). Median IFs for these categories differ less, but nevertheless quite significantly -- almost 4-fold. Variation of the normalized Sen and Marshakova-Shaikevich IF values for journals occupying the same rank position in different categories is also considerable. See coefficient of variation (C.V.) column in Table 1. Our rnIFs are much less variable. The C.V. of rnIF varies from 0.6% to 2.4%, which greatly contrasts with the C.V. values of the *JCR* IF which vary from 57.1% to 86.0%, or of SnIF: from 12.3% to 77.8%, or MnIF: from 2.4% to 22.22%. The other advantage of rnIF is its straightforward interpretation. For example, consider the second highest journal in each *JCR* category. Sen's nIF varies from 63.7 to 100. Marshakova-Shaikevich's nIF varies from 92.26 to 137.58. Thus, it is difficult to judge the status of a journal in its subject category by its nIF values. Our rnIFs are more transparent in their meaning. They indicate the proportion of journals in their subject category, which have higher IF values. Thus rnIFs for the journals ranked 2nd in each category range from 0.982 to 0.997, which means there are only 1.8% to 0.3% of journals with higher IFs.

The rnIF may also be useful when considering the citation rank of a journal among the global set of journals covered by *JCR*. For example, the 2002 IF of *Genetics* is 4.483. The IF tells us that the average paper published in 2000 or 2001 was cited 4.483 times in 2002. Is that a high citation frequency? Of 5876 journals covered by *JCR* in 2002, how many have higher IF? The global rnIF will provide the answer: $rnIF = (5876-302+1)/5876 = 0.948$. This means that only 5.2% of journals in the global set have an IF values higher than *Genetics*. The global rnIF tells us that this journal is near the 95th percentile of the distribution of the global set of journals.

Using three IF values (the standard one, the global rnIF, the specialty rnIF) provide a more complete characterization of the citation rank of a journal. The standard IF gives an absolute measure of citation frequency, regardless of discipline, the global rnIF shows its citation rank relative to the global set, and the specialty rnIF shows its citation rank within its specialty. The global rnIF of 0.948 for *Genetics* testifies that it is indeed a globally

Table 1. Average values and coefficients of variation of *JCR* IFs, SnIF, MnIF, and rnIF for 6 journals in 5 different *JCR* categories (Agronomy, Genetics & Heredity, Biotechnology & Applied Microbiology, Biochemistry & Molecular Biology, Physics, multidisciplinary). Journals in each category include the 5 highest and the median when sorted by IF. The journal titles are given in the Table 2.

Journal Rank		Agronomy	Genetics & Heredity	Biotechnology & Applied Microbiology	Biochemistry & Molecular Biology	Physics, Multidisciplinary	Mean	Standard Deviation	Coefficient of Variation, %
	Number of journals in *JCR* category	57	114	134	310	69			
1	IF	2.419	30.910	13.810	43.429	12.774	20.668	16.320	78.96
	SnIF	100	100	100	100	100	100	0	0
	rnIF	1	1	1	1	1	1	0	0
	MnIF	116.07	146.04	164.62	153.62	191.95	154.46	24.712	16.00
2	IF	2.418	19.676	11.542	32.440	9.000	15.015	11.536	76.83
	SnIF	100.00	63.7	83.6	74.7	70.5	78.5	14.0	17.83
	rnIF	0.982	0.991	0.992	0.997	0.986	0.990	.006	0.60
	MnIF	116.03	92.96	137.58	114.75	135.24	119.31	16.21	13.58
3	IF	2.358	13.810	7.615	27.905	8.756	12.089	9.733	80.51
	SnIF	97.4	44.7	55.1	64.2	68.5	66.0	19.8	30.00
	rnIF	0.965	0.982	0.985	0.994	0.971	0.979	0.012	1.23
	MnIF	113.15	65.25	90.77	98.71	131.57	99.89	22.20	22.22
4	IF	1.588	13.450	6.796	26.300	7.110	11.049	9.506	86.03
	SnIF	65.6	43.5	49.2	60.6	55.7	54.9	8.8	16.03
	rnIF	0.947	0.974	0.978	0.990	0.956	0.969	0.018	1.86
	MnIF	76.20	63.55	81.01	93.03	106.84	84.12	14.77	17.56
5	IF	1.313	12.912	5.964	18.195	6.462	8.969	6.607	73.66
	SnIF	54.3	41.8	43.2	41.9	50.6	46.4	5.7	12.28
	rnIF	0.930	0.965	0.970	0.987	0.942	0.959	0.023	2.40
	MnIF	63.00	61.00	71.09	64.36	97.10	71.31	13.33	18.70
Median	IF	0.500	1.964	0.973	1.882	0.671	1.198	0.684	57.10
	SnIF	20.7	6.4	7.0	4.3	5.2	8.72	6.78	77.75
	rnIF	0.509	0.504	0.504	0.502	0.507	0.505	0.003	0.59
	MnIF	23.99	9.28	11.60	6.66	10.08	12.32	6.05	49.11

high impact journal being among the top 5 or 6% of journals in impact. Its specialty rnIF of 0.809 indicates that it is well cited compared to other journals in the *JCR* Genetics & Heredity category. Its higher global value means that the category includes many fast moving journals where the median journal IF is higher than the median of the global set. For slower moving specialties the opposite relation between the global and specialty rnIF will be true.

Testing Effectiveness of the Rank Normalized Impact Factor

To verify the effectiveness of the proposed normalization scheme we used bibliographic data on the top cited scientists in seven different specialties. ISI regularly publishes data online for the most-cited authors worldwide (see www.isihighlycited.com for the latest ten-year period).

Table 2. The titles of the journals characterized in the Table 1.

***JCR* category & journal title**	**IF rank within *JCR* category**	**IF**
Agronomy		
Advances in Agronomy	1	2.419
Molecular Breeding	2	2.418
Theoretical and Applied Genetics	3	2.358
Agricultural and Forest Meteorology	4	1.588
Postharvest Biology and Technology	5	1.313
Applications	median	0.500
Genetics & Heredity		
Nature Genetics	1	30.910
Genes & Development	2	19.676
Current Opinion in Genetics & Development	3	13.810
Annual Review of Genetics	4	13.450
Trends in Genetics	5	12.912
Current Genetics AND Mutation Research - Genomics	median*	1.964
Biotechnology & Applied Microbiology		
Current Opinion in Genetics & Development	1	13.810
Nature Biotechnology	2	11.542
Genome Research	3	7.615
Human Gene Therapy	4	6.796
Gene Therapy	5	5.964
Journal of Fermentation and Bioengineering AND Biotechnology Letters	median*	0.973
Biochemistry & Molecular Biology		
Annual Review of Biochemistry	1	43.429
Cell	2	32.440
Nature Medicine	3	27.905
Annual Review of Cell and Developmental Biology	4	26.300
Molecular Cell	5	18.195
Mechanisms of Aging and Development AND Methods – A Companion to Methods in Enzymology	Median*	1.882
Physics, multidisciplinary		
Reviews of Modern Physics	1	12.774
Reports on Progress in Physics	2	9.000
Journal of Physical and Chemical Reference Data	3	8.756
Physics Reports – Review Section of Physics Letters	4	7.110
Physical Review Letteres	5	6.462
Brazilian Journal of Physics	Median	0.671

*When the number of journals in a *JCR* category is even, there are two median journals; hence the median IF value is the average of these 2 median journals.

These data are freely available to all users. We retrieved bibliographic information on the five most recent papers of an arbitrarily chosen person in each of seven specialties in that database: Physics, Animal & Plant Sciences, Molecular Biology & Genetics, Engineering, Immunology, Pharmacology, and Neurosciences -- 35 papers in all, published in 28 journals in 1996-2001. See Tables 3 and 4. For each journal we determined the rnIF and the two other Sen and Marshakova-Shaikevich nIFs. All the information necessary for computation of the three normalized IFs was taken from the 2000 edition of *JCR*. Note that the categories in these two databases, *JCR* vs. *ISI's Highly-Cited*, are not identical. For example, a physicist may have published in journals that are assigned to one or more *JCR* physics categories whereas there is only one physics category in *ISIHighlyCited.com*.

Table 3. Journals in which 35 papers by the 7 highly cited authors were published, sorted by category. Note that these are somewhat different than *JCR* categories.

ISIHighlyCited Specialties* **& Journals where papers were published**	**Year of publication**	**IF**	**rnIF**
Animal & Plant Sciences			
1. Protist	2001	2.351	.706
2. Applied and Environmental Microbiology	2001	3.389	.870
3. Science	2001	23.872	.980
4. Aquatic Microbial Ecology	2001	2.190	.874
5. Marine Ecology - Progress Series	2001	1.928	.842
average		**6.746**	**.854**
Engineering			
1. Environmental Science & Technology	2000	3.035	.992
2. Environmental Science & Technology	2000	3.035	.992
3. Atmospheric Environment	2000	1.942	.832
4. Environmental Science & Technology	2000	3.035	.992
5. Environmental Science & Technology	2000	3.035	.992
average		**2.816**	**.930**
Immunology			
1. Genes & Development	1998	19.676	.981
2. Science	1998	23.872	.980
3. Genes & Development	1997	19.676	.981
4. Journal of Experimental Medicine	1996	15.236	.978
5. Journal of Experimental Medicine	1996	15.236	.978
average		**18.739**	**0.980**
Molecular Biology & Genetics			
1. EMBO Journal	2001	13.999	.968
2. Journal of Leukocyte Biology	2001	4.342	.868
3. Trends in Biochemical Sciences	2001	13.246	.971
4. Genetics	2000	4.687	.860
5. Genes & Development	2000	19.676	.981
average		**11.190**	**.930**
Neurosciences			
1. Neuroimage	2000	6.857	.977
2. Biological Psychiatry	2000	4.269	.882
3. Neuroreport	2000	2.696	.700
4. Journal of Neuropsychiatry and Clinical Neurosciences	2000	2.140	.692
5. Journal of Child Neurology	2000	1.134	.580
average		**3.419**	**.766**
Pharmacology			
1. Respiratory Medicine	2001	1.254	.483
2. Thorax	2001	3.979	.931
3. European Respiratory Journal	2001	2.590	.828
4. Clinical and Experimental Allergy	2001	2.947	.854
5. Journal of Allergy and Clinical Immunology	2001	4.179	.936
average		**2.990**	**.806**
Physics			
1. Journal of the European Ceramic Society	2001	0.952	.840
2. Applied Physics Letters	2001	3.906	.986
3. Journal of Vacuum Science & Technology, B	2001	1.605	.857
4. Journal of Applied Physics	2001	2.180	.957
5. Journal of Materials Research	2000	1.315	.863
average		**1.992**	**.906**

*Only one author represents each specialty

Table 4. Journals in which 35 papers of the 7 highly cited authors were published, sorted alphabetically. Columns: **A** gives the number of journals in the *JCR* subject category, **B** gives the *JCR* IF rank of the journal in the category, **C** is rnIF within the category, **D** is the rnIF of the journal, averaged over the categories to which it is classified.

No.	Journal	IF	*JCR* Subject Categories	A	B	C	D
1	Applied and Environmental Microbiology	3.389	Biotechnology & Applied Microbiology	134	15	.896	.870
			Microbiology	83	14	.843	
2	Applied Physics Letters	3.906	Physics, applied	70	2	.986	.986
3	Aquatic Microbial Ecology	2.190	Ecology	100	22	.790	.874
			Marine & Freshwater Biology	71	4	.958	
4	Atmospheric Environment	1.942	Environmental Sciences	127	12	.913	.832
			Meteorology & Atmospheric Sciences	40	11	.750	
5	Biological Psychiatry	4.269	Neurosciences	203	29	.862	.882
			Psychiatry	82	9	.902	
6	Clinical and Experimental Allergy	2.947	Allergy	15	2	.933	.854
			Immunology	116	27	.776	
7	EMBO Journal	13.999	Biochemistry & Molecular Biology	310	8	.977	.968
			Cell Biology	147	7	.959	
8	Environmental Science & Technology	3.035	Engineering, environmental	36	1	1.000	.992
			Environmental Sciences	127	3	.984	
9	European Respiratory Journal	2.590	Respiratory System	29	6	.828	.828
10	Genes & Development	19.676	Developmental Biology	33	2	.970	.981
			Genetics & Heredity	114	2	.991	
11	Genetics	4.687	Genetics & Heredity	114	17	.860	.860
12	Journal of Allergy and Clinical Immunology	4.179	Allergy	15	1	1.000	.936
			Immunology	116	16	.871	
13	Journal of Applied Physics	2.180	Physics, applied	70	4	.957	.957
14	Journal of Child Neurology	1.134	Clinical Neurology	137	66	.526	.580
			Pediatrics	71	27	.634	
15	Journal of the European Ceramic Society	0.952	Materials Science, Ceramics	25	5	.840	.840
16	Journal of Experimental Medicine	15.236	Immunology	116	3	.983	.978
			Medicine, research & experimental	74	2	.973	
17	Journal of Leukocyte Biology	4.342	Cell biology	147	28	.816	.868
			Hematology	60	7	.900	
			Immunology	116	14	.888	
18	Journal of Materials Research	1.315	Materials Science, multidisciplinary	168	24	.863	.863
19	Journal of Neuropsychiatry and Clinical Neurosciences	2.140	Clinical Neurology	137	34	.759	.692
			Neurosciences	203	83	.596	
			Psychiatry	82	24	.720	
20	Journal of Vacuum Science & Technology, B	1.605	Engenieering, electrical & electronic	204	19	.912	.884
			Physics, applied	70	11	.857	
21	Marine Ecology - Progress Series	1.928	Ecology	100	27	.740	.842
			Marine & Freshwater Biology	71	5	.944	
22	Neuroimage	6.857	Neurosciences	203	15	.931	.977
			Neuroimaging	15	1	1.000	
			Radiology, Nuclear Medicine & Medical Imaging	80	1	1.000	
23	Neuroreport	2.696	Neurosciences	203	62	.700	.700
24	Protist	2.351	Biology, miscellaneous	62	18	.726	.706
			Microbiology	83	27	.687	
25	Respiratory Medicine	1.254	Cardiac & Cardiovascular System	63	27	.587	.483
			Respiratory System	29	19	.379	
26	Science	23.872	Multidisciplinary Sciences	49	2	.980	.980
27	Thorax	3.979	Respiratory System	29	3	.931	.931
28	Trends in Biochemical Sciences	13.246	Biochemistry & Molecular Biology	310	10	.971	.971

Table 5. Average values of IF, nIF after Sen, nIF after Marshakova-Shaikevich, and rnIF for the journals where the 5 most recent papers of 7 top cited scientists in each specialty were published. The categories are those used in the *ISIHighlyCited.com* database. Note that these are somewhat different than *JCR* categories.

Specialty in *ISIHighlyCited.com*	IF	SnIF	MnIF	rnIF
Animal & Plant Sciences	6.746	43.44	61.98	0.854
Engineering	2.816	81.71	98.81	0.930
Immunology	18.739	63.16	110.45	0.980
Molecular Biology & Genetics	11.190	34.64	58.51	0.930
Neurosciences	3.419	30.09	48.35	0.766
Pharmacology	2.990	46.52	53.34	0.806
Physics	1.992	39.68	64.65	0.906
mean	6.842	48.45	70.87	0.886
ratio max/min	9.41	2.72	2.28	1.28
C.V., %	89.9	37.3	33.4	9.0

Table 6. Impact Factors for *Genetics* and numbers of journals in *JCR* category of "Genetics & Heredity," 1997 to 2002

Year	*JCR* IF	rnIF	SnIF	MIF	Max IF in *JCR* category Genetics & Heredity	Number of journals	Rank of the journal *Genetics*	Weighted average of IF of top 5 journals
1997	4.275	0.833	11.00	23.35	38.85	90	16	18.31
1998	4.450	0.864	11.03	20.39	40.36	103	15	21.83
1999	4.221	0.838	13.75	23.62	30.69	105	18	17.87
2000	4.687	0.860	15.16	22.14	30.91	114	17	21.17
2001	4.803	0.832	16.23	22.36	29.60	113	20	21.48
2002	4.483	0.809	16.78	24.09	26.71	115	23	18.61
mean	4.4865	0.8393	13.992	22.659	32.855	106.7	18.2	19.877
C.V.,%	5.05	2.42	18.07	5.91	16.62	8.97	16.11	9.03

By definition, all the scientists chosen are highly cited. Thus, if our normalization is effective, the average values of rnIF among these scientists should be much more similar than those obtained from the *JCR*. Table 5 displays the average values of *JCR* IF, SnIF, MnIF and rnIF for the seven scientists. One can see that the *JCR* IF values are very different among these top scientists. For example, the average IF for the physicist is 1.992 while the IF average for the immunologist is 18.739, almost a ten-fold difference.

The difference in our rnIF is much lower: 0.906 and 0.980. The coefficient of variation (C.V.) of the *JCR IF* is 89.9% while it is only 9.0% for rnIF. Normalized values according to Sen and Marshakova-Shaikevich reduce the differences among disciplines, but the variation is still considerable: C.V. values are 37.3% and 33.4%.

We reiterate, the scientists under consideration are the most-cited authors in their respective fields for the last decade. Not surprisingly, and in accord with their high rank, their papers are usually, but not always, published in the most influential journals. This is revealed by our rnIF: only one paper of 35 (2.9%) was published in a journal with IF less than the median (rnIF = 0.492). Thirty papers of the 35 (85.7%) were published in journals with rnIF higher than 0.82 and thus within 18% of the highest IF journals. Using the *JCR* IF values does not produce these easily interpretable results across fields. Unfortunately, the normalization procedures suggested by Sen (1992) and Marshakova-Shaikevich (1996) do not prove to be sufficiently effective.

Evidently, the efficiency of the suggested normalization depends on the quality of the journal categorization provided by the *JCR*. ISI's heuristic categorization procedure is not ideal. Unfortunately, an ideal categorization procedure is not yet available. This was noted in our recent study of journal relatedness (Pudovkin & Garfield, 2002). The more realistic the categorization, the more efficient the suggested normalization across fields will be. For journals assigned to several categories, the averaging of the rnIF values would require knowledge of the relevance of the journals to the categories. Relevancy weight could be used to improve averaging. We have used equal weights since relevancies were not available. As a concrete example, the *JCR* category for neurosciences includes neurology journals. The latter have, on average, IFs lower than the less clinically and more molecularly oriented journals in neuroscience. This accounts in part for the lower rnIF for the neuroscientist. The rnIF for the neuroscientist would be even higher if papers from the neurology journals were not included.

Table 6 shows time variation of the IF values for the journal *Genetics* from 1997 to 2002. One can see that the rnIF is the most chronologically stable one. It ranges from 0.809 in 2002 to 0.864 in 1998. C.V. for the six-year values equals only 2.42%. The *JCR* IF is the next in its time stability, C.V. equals 5.05%. The values of Sen and Marshakova-Shaikevich are more time variable: C.V. values for them are 18.07% and 5.91%.

Discussion

Warner (2003) reports on the results of the Research Assessment Exercises in the UK and concludes that "the only system that will enjoy both the confidence and the consent of the academic community is one based ultimately upon expert reviews." However, he admits that "use of citation analysis and other performance indicators is consistent with its informative role." We agree that normalized citation data can provide a useful objective reference scale to aid experts in evaluating scientists' performance. As was mentioned above in some countries grant application evaluation routinely involves use of the *JCR* IF to rate the applicant's publications. The procedure adopted in the Physico-Chemical Biology Program of the Russian Academy of Sciences (Georgiev, 2003) takes into account not only *JCR* values, but also the order of the applicant's name in the author byline which seems to us unreasonable. The order is quite erratic across journals and varies with cultural preferences. However, the use of journal IFs for evaluatory purposes meets even stronger objections. Adam (2002) quotes a conversation with Anthony van Raan, who describes the use of IFs to evaluate scientists' publications "the poor man's citation analysis." Certainly, actual citation scores would provide a better performance indicator. But this is not ordinarily possible for recently published papers. The time lag in citation makes citation scores almost useless in evaluating grant applications. In this case ranking the journals in which an applicant has published is the next best choice. An exception would be hot papers. However, most of these appear in high impact journals. Evaluators may give undue weight to the highest impact journals. It is more important that they rank journals within their respective *JCR* categories. The meaning of that rank is dependent upon the number of journals in the category. If one category contains 300 journals and another 20, then the 10th journal in each category will have a very different meaning. In the larger category, the 10th journal is of high citation status, while in the smaller category the 10th journal will be just the median. The rnIF rank ordering procedure takes care of the differences in citation rates and field size. Thus, for the examples above, the 10th journals will have the following rnIF values: 0.970 and 0.550 meaning that in the larger category only 3% of its journals have higher IFs but in the smaller category 45% of the journals have higher IFs.

Evaluation procedures involving journal IF may be especially important for smaller countries, where establishing evaluation committees that include competent experts across many science fields is difficult. In these situations, this "poor man's citation analysis" seems warranted. The success of the use of citation indicators in the Research Assessment Exercises in the UK indicates that citation methods are preferable to the often arbitrary and uninformed subjective methods of peer review groups – not to mention the expense (Oppenheim, 1977; Norris & Oppenheim, 2003).

For the evaluation of an individual scientist's or a research collective's contribution, we would recommend using *JCR* IF values in combination with rank-normalized ones. The former are indicative of the unquestionable evidence of professional excellence among the applicant's publications (e.g. papers accepted by *Science*, *Nature*, *PNAS*, or other first rate journals). The mere acceptance by a leading international journal has much greater significance in the developing world. However, consideration of rank-normalized IF would prevent the underestimation of productive scientists from less hot slower moving specialities. Computation of the suggest rnIF is quite simple since all the necessary values are provided by the *JCR*. This would be less tedious if ISI were to publish the average and median IFs for each category.

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REFERENCES

Adam, D. (2002). The counting house. Nature, 415, 726-729.

Amin, M., & Mabe, M. (2002). Impact factors: Use and abuse. Perspective in Publishing, No. 1, 1-6.

Garfield, E. (February 2, 1998). Long-term vs. short-term impact: Does it matter? The Scientist, 12(3), 11-12. Retrieved May 26, 2004 from http://www.thescientist.com/yr1998/feb/research_980202.html

Garfield, E. (July 6, 1998). Long-term vs. short-term impact: Part II, The Scientist, 12(14), 12-13. Retrieved May 26, 2004 from http://www.the-scientist.com/yr1998/july/research_980706.html

Garg, K.C., & Padhi, P. (1999). Scientometrics of laser literature as viewed through the Journal of Current Laser Abstracts. Scientometrics, 45, 251-268.

Garg, K.C. (2001). Scientometrics of laser research in India and China. In M. Davis (Ed.), Proceedings of the 8th International Conference on Scientometrics and Informetrics Meeting, University of New South Wales, Sydney (ISSI 2001) (Volume 1, p.167-177). Sydney: Bibliometric & Informetrics Group, University of New South Wales.

Georgiev, G.P., (2003). Strong and efficient. Poisk, 10(720), 5-6 (in Russian).

Lawrence, P.A. (2002). Rank injustice: The misallocation of credit is endemic in science. Nature, 415: 835-836.

Marshakova-Shaikevich, I. (1996). The standard impact factor as an evaluation tool of science and scientific journals. Scientometrics, 25, 283-290.

Marshakova-Shaikevich, I. (2003). Bibliometric evaluation of Russian science journals. Vestnik Rossiiskoi Akademii Nauk (The Herald of Russian Academy of Sciences), 73(9), 788-796. (in Russian).

Norris, M., & Oppenheim, C. (2003) Citation counts and the Research Assessment Exercise V – Archeology and the 2001 RAE, Journal of Documentation 59, 709-739.

Oppenheim, C. (1997). The correlation between citation counts and the 1992 research assessment exercise ratings for British research in genetics, anatomy and archaelogy, Journal of Documentation, 53, 477-487.

Pudovkin A.I., & Garfield E. (November 2002). Algorithmic procedure for finding semantically related journals, Journal of the American Society for Information Science and Technology 53, 1113-1119. Retrieved May 26, 2004 from http://garfield.library.upenn.edu/papers/pudovkinsemanticallyrelatedjournals2002.html

Seglen, P. O. (February 15, 1997). Why the impact of journals should not be used for evaluating research, British Medical Journal 314(7079), 498-502.

Sen, B.K. (1992) Normalized impact factor. Journal of Documentation, 48, 318-329.

Warner, J. (2003) Citation analysis and research assessment in the United Kingdom. Bulletin of the American Society for Information Science and Technology, 30, 26-27.