Scientometrics, Vol. 26. No. 1 (1993) 21-35

REFERENCE STANDARDS FOR CITATION BASED ASSESSMENTS

A. SCHUBERT, T. BRAUN

Information Science and Scientometrics Research Unit (ISSRU),
Library of the Hungarian Academy of Sciences,
P.O.Box 7, H-1361 Budapest (Hungary)

(Received January 6, 1992)

One of the most crucial points of citation-based assessments is to find proper reference standards to which the otherwise meaningless plain citation counts can be compared. Using such standards, mere absolute numbers can be turned into relative indicators, suitable for cross-national and cross-field comparisons. In the present study, three possible choice of reference standards for citation assessments are discussed. Citation rates of publications under study can be compared to the average citation rates of the papers of the publishing journals to result in *Relative Citation Rate* (*RCR*), an indicator successfully used in several comparative scientometric analyses (see, e.g. Refs 1-5). A more "customized" reference set is defined by the *related records* in the new CD Edition of the *Science Citation Index* database. Using the so-called "bibliographic coupling" technique, a set of papers with a high measure of similarity in their list of references is assigned to every single paper of the database. Beside of being an excellent retrieval tool, related records provide a suitable reference set to assess the relative standing of a given set of papers as measured by citation indicators. The third choice introduced in this study is specifically designed for assessing journals. For this purpose, the set of journals cited by the journal in question seems to be a useful basis to compare with. The pros and cons of the three choices are discussed and several examples are given.

Introduction

It has long been stressed by the present authors[1-5] as well as by others[6-7] that citation counts can be used for evaluative purposes only after proper standardization. Citation rate of papers of not necessarily the same age and topic cannot be compared directly but each of them must first be compared to the citation rate of a set of papers sharing their main characteristics with the papers in question and the relative standing of the papers in their respective *reference standard* set can then be compared. As *Garfield*[7] suggests: "Instead of directly comparing the citation count of, say, a mathematician against that of a biochemist, both should be ranked with their peers, and the comparison should be made between rankings. Using this method, a mathematician who ranked in the 70 percentile group of mathematicians would have

Elsevier, Amsterdam - Oxford - New York - Tokyo
Akadémiai Kiadó

an edge over a biochemist who ranked in the 40 percentile group of biochemists, even if the biochemist's citation count was higher."

There still remains the question: how to find the most suitable company of "peers" or reference set of papers to perform the primary comparison. In some fortunate cases one may rely upon the experts' opinion but, especially if a large manifold of papers is to be assessed, such help cannot be expected. Some simple methods are to be found, which, as it were, automatically assign the reference standards to the papers under investigation.

In the present study, three possibilities are outlined to "generate" such reference standards. Evidently, none of the suggested methods is as reliable as a well-considered expert selection. It must be, however, also understood that in most practical cases even a somewhat more sophisticated "automatic" method may surpass the limitations of the analysis (as regards time, computer capacity or money). The comparative advantages of the methods will, therefore, be emphasized to help the analyst to find at least a "suboptimal" solution to the problem of selecting a reference standard for citation assessments.

The publishing journal as reference standard

Primary journals in science are generally agreed to contain coherent sets of papers both in contents and in professional standards. This coherence stems from the fact that most journals are nowadays specialized in quite narrow subdisciplines and their "gatekeepers" (i.e., the editors and referees) controlling the journal are members of an "invisible college" sharing their views on questions like relevance, validity or quality.

It seems, therefore, justified to expect the same level of citation rate for papers published in the same journal in the same time. If two such papers receive a different number of citations, one may rightly suspect that this reflects differences in their inherent qualities. By comparing the number of citations received by a paper (or the average citation rate of a subset of papers published in the same journal – the *Mean Observed Citation Rate, MOCR*) to the average citation rate of all papers in the journal (the *Mean Expected Citation Rate, MECR*), the *Relative Citation Rate* (*RCR*) will be obtained. This indicator shows the relative standing of the paper (or set of papers) in question among its close companions: its value is higher/lower than unity as the sample is higher/lower cited than the average.

As an example, consider the *RCR* of papers in the journal *Acta Chimica Hungarica* by the nationality of the first author[5] (Table 1).

Table 1
Acta Chimica Hungarica (1981-1985)
Nationality of first authors ranked by *RCR*

Country	Number of papers	RCR
Hungary	328	1.33
Poland	26	1.13
Czechoslovakia	11	0.70
Belgium	11	0.49
Egypt	28	0.47
India	145	0.42
German DR	16	0.41

It can be seen that only Hungarian and Polish authors receive, in the average, more than expected citations. The result may serve as a hint for the gatekeepers of the journal to be more critical with authors from countries cited lower than average.

In general, sets of papers under investigation are published in various journals. In that case, the mean expected citation rate (*MECR*) can be defined as the weighted average citation rate of the journals, the papers in question were published in. (The weights are, of course, the publication frequencies in the respective journal.) The mean observed citation rate (*MOCR*), i.e., the average citation rate per paper can again be related to the *MECR* to result in the relative citation rate (*RCR*), indicating the relative impact of the papers in question among the average papers of the publishing journals as reference standard.

Taking the output of the seven countries of Table 1 as an example, but in this case not in a single journal but in all chemistry journals covered by *SCI* in the period 1981-1985, the following results are obtained[5] (Table 2).

It can be seen that none of the seven countries in question reached the average citation level of the journals where they published. In fact, in the 1981-1985 period ten countries received higher than expected citation rate: Denmark (*RCR* = 1.25), Switzerland (1.22), Netherlands (1.12), Sweden (1.12), USA (1.07), UK (1.07), FR Germany (1.06), Canada (1.05), Australia (1.05), and Norway (1.05). Table 1 also shows that although the GDR and Czechoslovakia approach the closest the standard set by the publishing journals, Belgium and Hungary reach their somewhat lower *RCR* scores in higher impact journals. How to interpret these differences is a question requiring deeper analysis: whether differences in the fine structure of research subfields are responsible for the different *MECR* values in the countries concerned or they just follow different publication strategies. It is, nevertheless, a warning signal that even relative indicators must not be used "one-dimensionally". As a simple alternative a two-dimensional "relational chart" of *MOCR* vs. *MECR* may be suggested.

Table 2
Chemistry journals (1981-1985)
Nationality of first authors ranked by *RCR*

Country	Number of papers	MECR	RCR
German DR	3662	1.58	0.93
Czechoslovakia	4433	1.67	0.92
Belgium	2037	2.77	0.91
Hungary	2397	2.01	0.87
India	13220	1.44	0.74
Poland	4552	1.82	0.71
Egypt	1757	1.44	0.60

This simple but useful tool can help to invalidate a frequently echoed objection against the use of *RCR*. It is naively supposed that it is easier to reach higher *RCR* values by notoriously publishing in low impact journals. (Data of Table 1, in a sense, support this view.) A look at the relational chart of chemistry (Fig. 1) will, however convince anybody that all countries reaching higher than expected citation rate ($RCR > 1$), have an expected citation rate (*MECR*) above the world average (which latter is represented by the vertical line: $MECR = 2.59$). It seems that citations even in local or lower standard journals can be attracted by regularly publishing in mainstream, high impact journals.

There are, nevertheless, some weaknesses inherent in using the publishing journal as reference standard: Papers published in multidisciplinary journals are measured by common standards, which might be clearly unfair, say, for a geoscience article published in *Nature* together with a molecular genetics paper. Since journals form a virtually continuous spectrum from highly specialized to multidisciplinary, and different research fields or even subcommunities in the same field may typically use different segments of this spectrum, the unbiassedness of the reference standards must be thoroughly checked whenever comparative assessments are based on the *RCR* indicator.

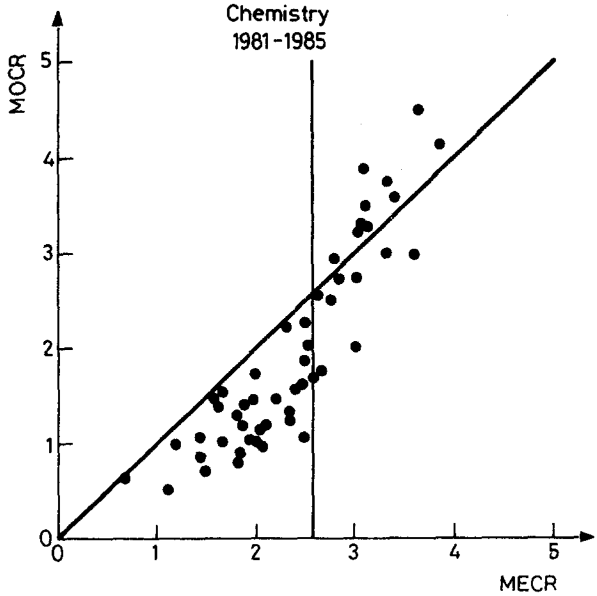

Fig. 1. Relational chart of observed *vs.* expected citation rates in chemistry (1981-1985)

As a rule, it can be said that in coherent research fields, where papers are usually published in specialized journals (what is the general trend in contemporary science), publishing journals as reference standards and *RCR* as indicator can readily be suggested for comparative assessments. It must, however, be added that even in such cases extension from one to two dimensions may multiply the effectivity of the analysis.

The set of related records as reference standard

"Bibliographic coupling" has first been suggested by *Kessler*[8] as a basis for document retrieval. This concept uses the number of references a given pair of documents have in common to measure the similarity of their subject matter. Collecting a set of "similar" papers, in this sense, to a given article and of the same age, an ideal reference standard can be obtained for citation assessments. This apparently simple and sraightforward method has long been practically unaccomplishable because of the technical difficulties of collecting the "coupled" papers, even by using any traditional version of citation indexes.

Fortunately, the situation has radically changed with the advent of the CD-ROM edition of the *Science Citation Index* database, which is now available for the 1980-1991 period. The *SCI CD Edition* uses bibliographic coupling under the name *related records*. Two records are considered "related" when they list a number of identical papers in their respective bibliographies. Related records of an article are other articles published during the same period that cite at least one of the same references that the "parent" article cited. Because they have references in common, an article and its related records are supposed to be also related by subject. In general, the more references in common, the stronger the subject similarity between two articles. The *SCI CD Edition* has a built-in possibility for searching related records: a maximum of 20 related records are avaible for any given record ranked by strength of relatedness.

In what follows, the results of an exploratory study of using *SCI CD Edition* for comparative evaluation of citation impact is reported.

The publication output of the Hungarian pharmaceutical company CHINOIN in 1986 was investigated. This choice was motivated by the fact that a few attempts have already been made to assess the research activity of this company by other scientometric methods. In addition, the unique and unmistakeable name of the firm gave an easy way to retrieve by corporate address search from the database the full publication list. By processing the search output, source data and related records were collected in separate files. Citations to all source papers and related records were then counted manually in the 1987 *SCI Citation Index* printed volumes. Average 1987 citation rates of papers published in 1986 were determined from the 1987 *SCI Journal Citation Reports*[9] for all journals publishing at least one source paper or related record.

Citation rates of CHINOIN publications and of "related records" could then be compared to each other and to their respective "expected" citation rates based on the average citation rates of the journals.

74 papers of the CHINOIN pharmaceutical company could be retrieved from the 1986 annual disk of the *SCI CD Edition*. 19 of them had no references and therefore no related records. Since these publications (mainly meeting abstracts) were not expected to be cited at all, they were excluded from the analysis. The other 55 papers received a total of 32 citations in 1987, instead of 57 that would be expected on the basis of the average citation rates of the publishing journals.

In the related record file, 924 occurences of 718 articles could be found (34 of them were CHINOIN publication). In total (multiple occurrences taken by proper multiplicity), 1153 citations would be expected and 931 were actually observed.

Expected and observed citation rate per paper are illustrated by Fig. 2.

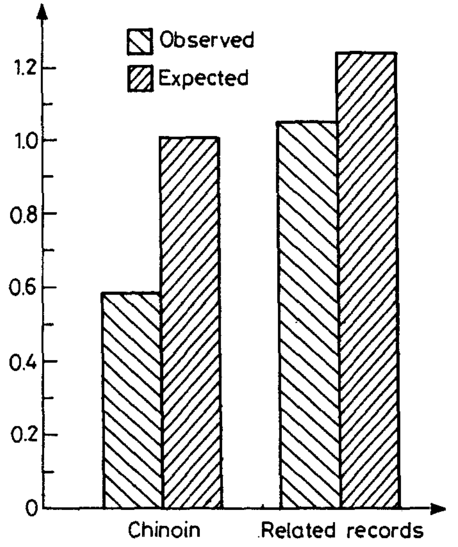

Fig. 2. Expected and observed citation rates of CHINOIN publications and "related records" (citations in 1987 to papers published in 1986)

Without getting involved into any statistical arguments, three simple but remarkable conclusions come to mind.

(1) Both for CHINOIN publications and for the "related records", observed citation rates per paper fall short of expected values. Thus, it seems that the research topics of CHINOIN are not the "hottest spots" of their respective subject field, which does not, however, qualify the research in any means.

(2) Although the expected citation rate of CHINOIN publications is rather close to that of the standard reference set ("related records"), their actual citation rate falls far below. Earlier studies concerning longer time periods did not show such a gap between expected and observed citation rates. The relatively low rate of subsequent year citations can most probably be attributed to insufficient informal, prepublication communication of research.

(3) The observed citation rate of the related records is conspicously identical with the expected citation rate of the "parent" CHINOIN publications. This finding, in a

sense, validates the use of relative scientometric indicators based on the comparison of actual with expected (journal average) citation rates. At least in the case of the present sample, the much more sophisticated "customized" control group – compiled on the principle of bibliometric coupling – set the same citation level as reference standard as did the simple journal average.

In subject fields less coherent than pharmaceutical research, however, the differences might be much more substantial, and the use of the set of related records as a more reliable reference standard certainly worth the surplus efforts.

The set of cited journals as reference standard

The set of publications to be assessed may represent various levels of aggregation, such as reserach teams, institutions, or whole research communities of a given subfield in a given country. In our experience, independently of the level of investigation, the publishing journal is a useful and reliable reference standard for citation assessments – having in mind the caveats earlier mentioned. In one particular case, however, this approach fails completely, namely, if journals themselves are subjected to comparative assessment. There is an ever growing interest in evaluation of journals by citation analysis (see, e.g., a bibliography of this topic in Ref. 9 or the review[10]), and one of the crucial questions also in this case is the comparison of journals publishing in science subfields of inherently different citation levels.

One possible solution might be again the use of related records. It is, however, practically impossible to retrieve the related records to every single article of just one volume of a medium size journal and to collect their citations.

Standardization of citation levels by subfields and comparing then the standardized scores has been attempted, among others, by the present authors[11,12]. This approach was found to be loaded with the inherent arbitrariness in the categorization of the journals into subfields and the ambiguity of treating inter- or multidisciplinary journals.

A method which now seems to provide the most satisfactory resolution at the lowest cost in terms of computer and/or manual search is based on the *journals in the reference lists of the articles of the journal in question*. These journals were selected by the most authentic persons, the authors of the journal as *references* (in both senses of the word) and, therefore, can justly be regarded as standards of the expected citation rate. Listings of journals cited by *SCI* covered journals are compiled in the

Citing Journal Package of the *Journal Citation Reports*[9]. A part of the 1985 data for *Acta Chimica Hungarica* is reproduced in Table 3.

Table 3
Journals cited by *Acta Chimica Hungarica* in 1985

Impact factor	Citing journal			Times cited
		Impact factor	Cited journal	
0.33	ACTA CHIM HUNG			833
		4.31	J AM CHEM SOC	45
		0.33	ACTA CHIM HUNG	39
		2.71	J CATAL	27
		1.97	TETRAHEDRON	19
			J CHEM SOC	15
			J CHEM SOC A	15
		3.09	J CHEM PHYS	13
			J INORG NUCL CHEM	13
		2.15	J ORG CHEM	13
			CRYST STRUCT COMMUN	11
		0.14	J INDIAN CHEM SOC	11
		2.08	TETRAHEDRON LETT	11
		2.42	J CHEM SOC CHEM COMM	10
		0.99	ORG MAGN RESONANCE	10
		0.98	B CHEM SOC JPN	9
		1.51	ANAL CHIM ACTA	8
		1.57	J ORGANOMET CHEM	8
		3.40	ANAL CHEM	7
		5.35	ANGEW CHEM INT EDIT	7
		2.63	INORG CHEM	7
		1.64	J MOL STRUCT	7
		0.35	MAGY KEM FOLY	7
		0.27	REACT KINET CATAL L	7
			ACTA PHARM HUNG	6
		0.37	DOKL AKAD NAUK SSSR	6
		2.01	J CHROMATOGR-BIOMED	6
		1.83	J ELECTROANAL CH INF	6
		1.64	ORG MASS SPECTROM	6
		0.45	PHARMAZIE	6
			ALL OTHER (324)	478

The impact factor of *Acta Chimica Hungarica* is 0.33, while the weighted average of the cited journals is 1.89 (only the individually listed journals having impact factor were averaged, the weights being the number of times they were cited). Thus, this journal reached a relative score of 0.33/1.89 = 0.174, i.e., got only 17.4 % of the citations received by its reference journal set.

Although this figure may seem rather dehonesting, it must be acknowledged that all but a very few journals fall far below the standard set by their references. This is because the general tendency of using the most prestigious sources to authorize, as it were, the citing articles. In every reserach area, a hierarchy of journals is set up with one or just a few journals on the top, and all others tend to cite "upwards".

A detailed study has been made on 2459 journals covered continuously by *SCI* in the period 1981-1985 and publishing at least 50 papers in these five years. Only 140 of them proved to be cited above the average of their cited references. This subset may rightly be considered the "chosen few" of the community of journals.

A closer look at this subset reveals that a considerable number of these journals are *review journals*, some of them having the word "review" even in their title. This is not too surprising, since review papers are well known to be cited much above the average. It is, however, interesting to realize that analysis of cited journals provides a simple means to distiguish review journals from "ordinary" ones. The indicator is the fraction of journal self-citations in all citations. Evidently, this fraction is much lower for review journals (collecting, by their very nature, references from a much wider pool of journals) than for primary journals. In our experience with the above sample of 2459 journals, 10 % is the dividing line under which, whatever its title, a journal is to be considered a review journal. In the Appendix, the top 140 journals are divided into two categories: primary journals (97 titles) having at least 10 % journal self-citation, and review journals (43 titles) under the critical 10 %. In both categories, the journals are arranged in descending order of their relative citation score (as compared to the average of their cited references).

The lists are worth studying in detail, and only the most conspicuous features are commented here. It is not surprising to find *Cell* at number one; having one of the highest impact factors of all journals, its outstanding position is evident. Some of the runner-ups are, however, clearly unexpected. The fact that some rather moderately cited journals score very high is partly due to the different hierarchical structure of different research areas. The relatively small number of chemistry journals in the top list can be attributed to the globally dominant position of a few journals, like *J. Am. Chem. Soc.* or *Analyt. Chem.*, in a rather wide research area. On the other extreme, mathematics is represented by a fair amount of journals, since there a "local hierarchy" seems to be set up in every single narrow subfield, each having its own leading journal. Otherwise, there is a reassuring balance of science fields and subfields both in the primary and the review journal lists.

Conclusions

Three methods has been suggested to establish reference standards for citation based assessments. All the three have their pros and cons, some of the indications and counterindications for their use have been discussed.

Using the publishing journal as reference standard and *RCR* as indicator appears to be the most generally applicable choice. Some alleged flaws (like motovating authors to publish in low impact journals) can easily be refuted, some limitations (e.g., the problems of inter- and multidisciplinary journals) are unavoidable.

Related records of the *SCI CD Edition* seem to provide an excellent customized reference set for every single paper. Although one cannot overestimate the significance of *CD-ROM* as the first tool making analyses using the bibliographic coupling technique feasible, these analyses may still encompass only a limited number of papers, if the required time and energy is to be kept within reasonable limits.

Using cited references as standard may open new vistas in citation analysis of journals as it has been demonstrated in a pioneering investigation in this study.

There are a lot of open questions in connection with the results presented here, which may and hopefully will form the topic of future research.

References

1. T. BRAUN, W. GLÄNZEL, A. SCHUBERT, *Scientometric Indicators. A 32-Country Comparative Evaluation of Publishing Performance and Citation Impact*, World Scientific Publ. Co., Singapore - Philadelphia, 1985.
2. T. BRAUN, W. GLÄNZEL, A. SCHUBERT, One more version of the facts and figures on publication output and relative citation impact of 107 countries, 1978-1980, *Scientometrics*, 11 (1987) 9-15.
   T. BRAUN, W. GLÄNZEL, A. SCHUBERT, One more version of the facts and figures on publication output and relative citation impact in the life sciences and chemistry, 1978-1980, *Scientometrics*, 11 (1987) 127-140.
   T. BRAUN, W. GLÄNZEL, A. SCHUBERT, One more version of the facts and figures on publication output and relative citation impact in physics and mathematics, 1978-1980, *Scientometrics*, 12 (1987) 3-16.
   T. BRAUN, W. GLÄNZEL, A. SCHUBERT, The newest version of the facts and figures on publication output and relative citation impact of 100 countries, 1981-1985, *Scientometrics*, 13 (1988) 181-188.
   T. BRAUN, W. GLÄNZEL, A. SCHUBERT, The newest version of the facts and figures on publication output and relative citation impact in the life sciences and chemistry, 1981-1985, *Scientometrics*, 14 (1988) 3-15.

T. BRAUN, W. GLÄNZEL, A. SCHUBERT, The newest version of the facts and figures on publication output and relative citation impact in physics, engineering, and mathematics, 1981-1985, *Scientometrics*, 14 (1988) 365-382.

3. A. SCHUBERT, W. GLÄNZEL, T. BRAUN, Against absolute methods: Relative scientometric indicators and relational charts as evaluation tools, In: A.F.J. VAN RAAN (Ed.), *Handbook of Quantitative Studies of Science and Technology,* North Holland, Amsterdam, 1988, pp 137-176.
4. T. BRAUN, W. GLÄNZEL, A. SCHUBERT, An alternative approach to the assessment of national performance in basic research, In: D. EVERED, S. HARNETT (Eds), *The Evaluation of Scientific Research,* Wiley, Chichester, 1989, pp 32-45.
5. A. SCHUBERT, W. GLÄNZEL, T. BRAUN, Scientometric datafiles. A comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields, 1981-1985, *Scientometrics*, 16 (1989) 3-478.
6. F. NARIN, *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity,* Computer Horizons, Inc., Cherry Hill, 1976.
7. E. GARFIELD, *Citation Indexing. Its Theory and Applications in Science, Technology, and Humanities,* Wiley, New York, 1979.
8. M.M. KESSLER, Bibliographic coupling between scientific papers, *American Documentation*, 14 (1963) 10-25.
9. E. GARFIELD (Ed.), *Science Citation Index, Journal Citation Reports. A Bibliometric Analysis of Science Journals in the ISI Database,* Institute for Scientific Information, Philadelphia, PA, USA, from 1975 annually
10. R. TODOROV, W. GLÄNZEL, Journal citation measures: A concise review, *Journal of Information Science*, 14 (1988) 47-56.
11. T. BRAUN, W. GLÄNZEL, A. SCHUBERT,, Subject field characteristic scores and scales for assessing research performance, *Scientometrics*, 12 (1987) 267-292.
12. W. GLÄNZEL, A. SCHUBERT, Characteristic scores and scales in assessing citation impact, *Journal of Information Science*, 14 (1988) 123-127.

Appendix

List of journals cited above their references

A. Primary journals

Rank	Title	Number of papers	Avg. cit. rate	Rel. cit. score	% of self-cit
1	CELL	2016	34.19	2.46	22 %
2	ARCH G PSYC	981	8.51	2.01	36 %
3	J ACM	269	2.22	1.95	57 %
4	PHYS REV L	6343	11.05	1.93	29 %
5	CIRCULATION	2254	10.42	1.79	29 %
6	J EXP MED	1579	22.94	1.76	21 %
7	J AM CHEM S	9148	9.04	1.69	36 %
8	ACT METALL	1086	4.08	1.55	39 %
9	ANALYT CHEM	3689	5.55	1.53	23 %
10	APPL PHYS L	4297	6.25	1.52	33 %
11	INVENT MATH	520	2.02	1.49	31 %
12	J CLIN PER	310	4.46	1.49	50 %
13	ANN MATH	191	3.16	1.48	41 %
14	J GRAPH TH	228	0.70	1.47	46 %
15	RADIOLOGY	3486	5.43	1.46	33 %
16	IEEE J Q EL	1423	5.97	1.43	30 %
17	NUCL SAFETY	231	0.68	1.42	44 %
18	IEEE AUTO C	1261	1.99	1.41	61 %
19	SIAM J NUM	413	1.81	1.41	45 %
20	P NAS US	8450	18.50	1.38	17 %
21	J DAIRY RES	319	3.08	1.38	50 %
22	ARCH R MECH	262	1.62	1.37	61 %
23	ANN STATIST	587	2.25	1.36	56 %
24	ANN SURG	1076	6.07	1.35	13 %
25	NUCL PHYS B	2643	9.73	1.34	36 %
26	P LOND MATH	255	1.36	1.34	39 %
27	J CLIN INV	2203	12.81	1.33	10 %
28	NATURE	8063	16.63	1.30	22 %
29	ASTROPH J S	362	9.17	1.30	10 %
30	PAP PUU	223	0.87	1.29	63 %
31	SIAM J CON	283	1.82	1.29	49 %
32	ASTROPHYS J	6168	8.09	1.28	61 %
33	CIRCUL RES	1036	10.47	1.26	19 %
34	INDI MATH J	271	1.31	1.26	38 %
35	ACT ODON SC	240	2.04	1.25	41 %
36	HUMAN FACT	292	1.16	1.24	68 %
37	BRAIN	233	6.93	1.24	11 %
38	ULTRASON IM	113	3.51	1.24	55 %
39	NEUROSCIENC	1201	9.86	1.24	14 %
40	INT STAT R	91	2.46	1.24	25 %
41	CLIN PHARM	1073	6.34	1.22	18 %
42	J CEREBR B	349	7.28	1.21	28 %
43	J EXP PSY A	158	4.22	1.21	42 %
44	ANTIM AG CH	2016	6.79	1.20	40 %
45	IEEE PATT A	445	1.84	1.20	48 %
46	J CELL BIOL	2319	15.63	1.19	25 %
47	J COMP NEUR	1717	8.60	1.18	28 %
48	INT J SOL S	437	1.41	1.18	54 %
49	ADV APPL P	250	1.32	1.17	37 %

Appendix

(cont.)

Rank	Title	Number of papers	Avg. cit. rate	Rel. cit. score	% of self-cit
50	TECHNOMET	206	2.04	1.17	42 %
51	J MECH PHYS	128	2.59	1.16	40 %
52	SCIENCE	5738	13.59	1.16	13 %
53	BR J ANAEST	947	4.09	1.15	39 %
54	ANN PROBAB	481	1.56	1.14	54 %
55	J ATMOS SCI	1139	5.11	1.13	55 %
56	N ENG J MED	7299	7.74	1.12	22 %
57	IBM J RES	323	2.90	1.11	85 %
58	SOL ENERG M	338	4.18	1.11	19 %
59	ASLE TRANS	316	0.98	1.11	58 %
60	J DIFF EQUA	483	1.06	1.11	37 %
61	J CHEM PHYS	8945	5.99	1.10	41 %
62	MATH PROGR	325	1.25	1.10	48 %
63	ECOLOGY	961	5.43	1.10	26 %
64	P IEEE	908	2.84	1.10	19 %
65	ANN INT MED	2740	7.24	1.10	18 %
66	AUST J ZOOL	333	1.41	1.10	74 %
67	J POL SC PP	952	3.39	1.09	30 %
68	J GEN PHYSL	421	10.51	1.09	19 %
69	NZ J AGR RE	361	1.26	1.08	66 %
70	J CLIN END	2203	8.12	1.08	27 %
71	GUT	965	5.75	1.08	20 %
72	AM J SCI	245	5.55	1.08	30 %
73	AUTOMATICA	389	1.70	1.07	27 %
74	CARIES RES	367	2.67	1.07	48 %
75	BLOOD	2086	10.85	1.07	20 %
76	OPERAT RES	419	1.15	1.07	61 %
77	MOLEC PHARM	887	9.57	1.06	13 %
78	LIMN OCEAN	657	5.42	1.06	29 %
79	J MARINE RE	231	5.61	1.06	16 %
80	J ANIM ECOL	336	4.15	1.05	30 %
81	ANN NUC ENG	326	1.09	1.05	54 %
82	GASTROENTY	2176	6.86	1.04	28 %
83	BIOMETRIKA	468	1.94	1.03	44 %
84	METALL T-A	1314	2.52	1.03	46 %
85	SURF INT AN	222	4.19	1.03	32 %
86	PSYCHOL REV	132	4.59	1.03	43 %
87	J PHARM EXP	2361	7.41	1.03	15 %
88	J GEOPH RES	5469	5.73	1.02	51 %
89	INT J HEAT	1160	1.50	1.02	28 %
90	J CATALYSIS	1660	5.06	1.02	49 %
91	DIABETES	1074	8.72	1.02	22 %
92	J NEURPHYSL	874	7.89	1.02	29 %
93	PHYS C GLAS	168	2.56	1.02	42 %
94	J BIOMECHAN	484	1.87	1.01	76 %
95	J FLUID MEC	1443	3.37	1.01	57 %
96	J PHYSL LON	2205	8.71	1.01	37 %
97	HYPERTENSIO	1034	6.93	1.00	20 %

Appendix

(cont.)

B. Review journals

Rank	Title	Number of papers	Avg. cit. rate	Rel. cit. score	% of self-cit
1	REV M PHYS	106	39.12	6.04	1 %
2	ANN R BIOCH	152	63.11	5.14	1 %
3	PHYSIOL REV	101	36.42	4.19	0 %
4	ANN R PLANT	103	26.74	3.78	2 %
5	ENDOCR REV	108	27.52	3.17	1 %
6	CHEM REV	102	17.25	3.15	0 %
7	MICROBIOL R	95	30.98	2.90	0 %
8	ANN R PH CH	102	17.11	2.79	1 %
9	ANN R ASTRO	76	19.62	2.74	2 %
10	ANN R PHARM	122	21.84	2.71	0 %
11	ANN R NEUR	81	27.05	2.68	1 %
12	ACC CHEM RE	309	15.40	2.40	3 %
13	ECOL MONOGR	101	10.02	2.09	7 %
14	PROG ENERG	53	3.75	2.06	9 %
15	REP PR PHYS	123	12.24	2.05	0 %
16	MEDICINE	152	10.85	1.91	2 %
17	CHEM SOC RE	83	10.22	1.87	0 %
18	PHARM REV	57	14.21	1.86	0 %
19	ANN R ENTOM	93	8.66	1.83	3 %
20	BRAIN RES R	86	13.74	1.83	5 %
21	IMMUNOL REV	237	26.12	1.81	2 %
22	ANN R PHYSL	226	16.15	1.73	1 %
23	PHYS REPORT	352	11.46	1.72	1 %
24	ANN R ECOL	90	9.18	1.70	3 %
25	STRUCT BOND	57	10.93	1.68	0 %
26	CATAL REV	81	7.27	1.64	4 %
27	CLIN PHARMA	194	7.66	1.64	4 %
28	ANN R FLUID	83	6.31	1.61	8 %
29	COORD CH RE	265	6.07	1.60	0 %
30	ANN R MICRO	118	14.25	1.41	1 %
31	ANN R GENET	78	22.21	1.40	0 %
32	T CURR CHEM	119	6.81	1.31	1 %
33	PROG CARD	106	9.67	1.31	1 %
34	CRC C R BI	84	17.27	1.29	0 %
35	ANN R BIOP	95	13.47	1.24	1 %
36	BIOL REV	80	7.74	1.16	0 %
37	MED RES REV	77	7.69	1.10	0 %
38	REV GEOPHYS	266	5.42	1.03	1 %
39	J PETROLOGY	130	5.63	1.03	8 %
40	CELL CALC	189	8.13	1.02	3 %
41	PROG NEUROB	83	8.65	1.02	0 %
42	J ELEC MAT	297	4.00	1.02	8 %
43	ANN R PSYCH	97	5.25	1.00	7 %