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The effect of additional citations in the stability of *Journal Citation Report* categories

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Abstract We use a new approach to study the ranking of journals in JCR categories. The objectives of this study were to empirically evaluate the effect of increases in citations on the computation of the journal impact factor (JIF) for a large set of journals as measured by changes in JIF, and to ascertain the influence of additional citations on the rank order of journals according their new JIFs within JCR groups. To do so, modified JIFs were computed by adding additional citations to the number used by Thomson-Reuters to compute the JIF of journals listed in the JCR for 2008. We considered the effect on rank order of a given journal of adding 1, 2, 3 or more citations to the number used to compute the JIF, keeping everything else equal (i.e., without changing the JIF of other journals in a given group). The effect of additional citations on the internal structure of rankings in JCR groups increased with the number of citations added. In about one third of JCR groups, about half the journals changed their rank order when 1–5 citations were added. However, in general the rank order tended to be relatively stable after small increases in citations.

Keywords Journal impact factor · Journal citation report · Citations · Journal rankings

Introduction

The JIF is computed by Thomson-Reuters for each year (Y) according to the following equation (Glänzel and Moed 2002):

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$$\mathrm{JIF}(Y) = \frac{\mathrm{Citations\_in\_}Y\mathrm{\_to\_documents\_published\_in\_}Y1\mathrm{\_and\_}Y2}{\mathrm{Citable\_items\_published\_in\_}Y1\mathrm{\_and\_}Y2}$$

In the above equation $Y1$ and $Y2$ are the 2 years before Y. To calculate the numerator of the JIF, Thomson-Reuters counts citations to all types of documents, whereas the denominator includes only citable documents (Glänzel and Moed 2002; Golubic et al. 2008). The JIF is one of the most frequently used scientometric indicators and it is often used as a basis for decision-making for research grants, hiring, and even salaries. Thus analyses of this strategic research tool can yield much useful information about science dynamics.

However, scientists have mixed feelings on the use of JIF. For example, according the results of a questionnaire completed by about 1,700 researchers from 86 different countries, "the opinion is slightly above the median which could be understood as neither positive nor negative" (Buela-Casal et al. 2012, p. 281). Many scientists and journal editors have published letters or editorial comments with positive and negative opinions on JIFs and their use.

In 2012, the journal *Scientometrics* devoted an issue to problems with and alternatives to this important indicator (*Scientometrics*, vol. 92, issue 2, August: Special Discussion Issue on Journal Impact Factors). The lead paper in this issue addressed some interesting points (Vanclay 2012). In a comment on this paper, one of us suggested that an interesting research project would be to evaluate the effect of adding or removing citations in the equation used to compute the JIF (Campanario 2012).

A single citation is the minimum "amount" of impact that we can use to compute the JIF (Campanario, in revision). There is a similar situation in Physics. The minimum amount of electric charge that can be added to an atom is the charge associated to one free electron; there is no possible smaller amount of electric charge. In fact, electron charge is used as a unit in the Atomic Units system instead of the Coulomb, the unit used in the International System. If we were constructing atoms from electrons, neutrons and protons, we would be able to add only one electron (or neutron or proton) at a time, so the amount of electric charge added each time would be the charge of the electron (the charge of protons is equal but positive). Similarly, in scientometric studies the minimum amount of "impact" we can study is the impact associated with a single citation. Thus, while the number of citations is a discrete magnitude, the JIF is not.

Using a similar conceptual approach, Vinkler recently studied the possibility of increasing the Hirsch-index, π-index or CDS-index by increasing the number of publications or citations only by unity (Vinkler 2013). In their theoretical study the results obtained with the "successively built-up indicator" model showed that as the number of citations increases, the indices may increase substantially.

Althouse et al. (2009) studied the evolution of JIFs across fields and over time. They find that the average number of citations in reference lists had increased gradually. Thus, there is a kind of inflation of JIFs over time. They discovered also that field-specific variation in the fraction of citations to literature indexed by Thomson Scientific's Journal Citation Reports is the single greatest contributor to differences in JIFs. Togia and Tsigilis (2006) studied the stability of two JCR groups: "Education and Educational Research" and "Education, Special" from 2000 to 2005. They discovered that journals belonging to the "Education and Educational Research" category had relative stable JIFs. However this was not true for the other category. Tsigilis et al. (2010) examined the stability of JIF of journals in the group "Sport sciences". They discovered a increase in the median impact factor from 2000 to 2006 following a linear trend or even a quadratic trend.

Changes from the usual JIF to JIFs computed by adding 1, 2, or more citations could result in changes in the internal ranking of journals within their JCR groups. For example,

the 2008 JIF of the journal *Adv Insect Physiol* changed from 5.000 to 5.250 (5 %) when only one more citation was added to the number of citations used by Thomson-Reuters. This sharp change in JIF did not result in any change in rank because the JIF of the journal that precedes it in the JCR group is 11.918 (*Annu Rev Entomol*). Consider now the journal *Order* (JCR group Mathematics). The JIF of this journal would change from 0.333 to 0.356 by adding only one more citation to the number used by Thomson-Reuters to compute the JIF. This change would move the journal from position 173 in the JCR group ranking to position 164 (9 places). Had this journal obtained 5 additional citations that contribute to JIF, its rank position would have changed from 173 to 143 (30 places).

This point is relevant when studying the rank of journals in different JCR groups. Thomson-Reuters classifies journals in JCR groups according to their scope; consequently many journals are listed in two or more JCR groups. Journals are ranked within their JCR group according their JIF. In some countries, journals rank (rather than absolute JIF) is used to evaluate the scientific merit of papers published in a given journal. Thus, there is fierce competition among journals to occupy the leading positions within their JCR groups. It is accordingly not unusual for journals to advertise their JIF and JCR rank on their website, nor is it surprising that researchers prefer to submit their papers to journals that occupy the top positions in their JCR group ranking. We should keep in mind, however, that the typical distribution of JIFs within a given JCR group is highly skewed. As a consequence, small increases in this indicator for a given journal can result in significant changes in a given journal's rank position. This may happen particularly in journals that occupy positions in the middle or near the bottom of the ranking.

In light of these considerations, we suggest here a new approach to study the ranking of journals in JCR categories. The objectives of this study are:

1. to empirically evaluate the effect of additional citations on the computation of the JIF (i.e., changes in the JIF) in a large set of journals, and
2. to ascertain the influence of increases in citations on the rank order of journals according their JIFs within JCR groups.

Method

All journals included in the Science edition of the 2008 JCR with a JIF greater than zero were used in this study ($n = 6567$). The journals were distributed among 173 JCR groups. Note that many journals were included in two or more JCR groups. The following variables were used:

(a) Number of citations and articles used by Thomson-Reuters to compute the JIF
(b) JIF0: JIF as computed by Thomson-Reuters
(c) JIF*n*: JIF computed adding *n* citations to the number of citations used by Thomson-Reuters to compute the JIF. These new JIFs are designated JIF*n*, where $n = 1, 2, 3$, etc. This yields variables JIF1, JIF2, JIF3, and so on. All JIF*n* were rounded to 3 decimal places.
(d) CJIF*n*: Change in the JIF. This variable is computed by subtracting JIF0 from JIF*n* (for example CJIF3 = JIF3 − JIF0).
(e) R*n*: Rank of a given journal in its JCR group (according to the classification published by Thomson-Reuters) when JIF*n* is used (keeping all other values the same)
(f) CR*n*: Change in the rank position that a given journal would experience when its JIF is replaced with JIF*n*, keeping everything else equal. Obviously, regardless of whether

JIF*n* and JIF are computed to the same number of decimal places, CR*n* is always zero or positive.

In this study, rank is defined by the position of a given journal in its JCR group when all journals are ranked from highest to lowest JIF. Thomson-Reuters ranks journals with the same JIF at the same position. However, the rank of some journals depends of the number of other journals with the same JIF. For example, consider the journals *BMC Struct Biol*; *Clin Biomech*; *Comment Inorg Chem*; *Gold Bull*; *Int J Stroke*; *J Database Manage*; *J Microbiol Meth*; *J Muscle Res Cell M*; *Manual Ther*; *Oligonucleotides* and *Rev Chem Eng*. All these journals share the same 2008 JIF of 2.000. Their rank in the whole JCR database is 2,177 in all cases. The journal with the next highest rank is *Plant Soil* (2008 JIF = 1.998) and its JCR rank is 2188. Let us imagine that the JIF of *Plant Soil* increases from 1.998 to 2.001. Its rank position would then change from 2,188 to 2,177 (11 places). However, this journal would actually rise in rank order by only one position. To avoid this spurious increase, we used a more natural scheme in which rank order is always successive. In our example, *Plant Soil* rank associated with a JIF = 1.998 would thus be 2,178 instead of 2,188.

Box 1 illustrates the approach used to compute the effect on rank order of adding citations in the JIF formula. This box shows a set of journals in a given group ranked by JIF0. We computed the variable JIF1 by adding 1 citation to each journal, and compared the resulting rank order of each journal against the initial rank order (keeping everything else equal). In our example, all journals would maintain their original rank order except *IEEE T Aero Elec*. This journal's JIF would change from JIF0 = 1.024 to JIF1 = 1.028. Comparing JIF1 (1.028) to the old set of JIF0 numbers shows that this journal gained one position, because its JIF1 is higher than the JIF0 for the journal *AIAA J*, which was ranked third according to JIF0. In summary, if *IEEE T Aero Elec* received only 1 more citation that contributed to JIF0, it would move up in the rank order from fourth to third position (keeping everything else equal, i.e. keeping the JIF0s of other journals unchanged). The rank increase for *IEEE T Aero Elec* can be computed as Rank0 − Rank1 = 1 (last column in Box 1).

It is important to note that we compared the new JIF1 (or JIF2, JIF3 or JIF*n*) for a given journal with the old JIF0 of all journals in the JCR group. We were interested in what would happen when a given journal received one or more additional citations while all other inputs remained unchanged. We did not compare all the new JIF1s (or JIF2s, JIF3s, etc.) for all journals. Note that when the new JIF*n* for a given journal was equal to the old JIF0 of another journal, the rank corresponding to the JIF*n* was equal to the rank corresponding to the old JIF0 for the other journals. This decision minimized the possibility of spurious changes in rank order.

As noted above, many journals were included in two or more JCR groups. When this was the case, we computed the JCR group statistics for all JCR groups.

Simple descriptive statistics were used to report the distribution of changes in JIF for the whole set of journals and changes in rank positions within JCR groups.

Results and Discussion

Figure 1 shows the distribution of about 98 % of JCR journals according CJIF1, CJIF5 and CJIF10 respectively, this is, the changes in JIF from JIF0 to JIF1, JIF5 and JIF10. As can be seen, the distributions are very similar but the scales are different. The distributions are

Box 1 Example of computation of changes in rank within a given JCR group when a single citation was added to the number of citations that contributed to the JIF. See text for a detailed explanation

Journal	JIF0	R0	JIF1	R1	CR1
ESA Bull-Eur Space	2.561	1	2.576	1	0
Prog Aerosp Sci	1.944	2	2.000	2	0
AIAA J	1.025	3	1.027	3	0
IEEE T Aero Elec Sys	1.024	4	1.028	3	1
J Guid Control Dynam	0.995	5	0.997	5	0
J Aerospace Eng	0.907	6	0.926	6	0
J Propul Power	0.891	7	0.894	7	0
Aerosp Sci Technol	0.740	8	0.747	8	0
J Astronaut Sci	0.656	9	0.672	9	0

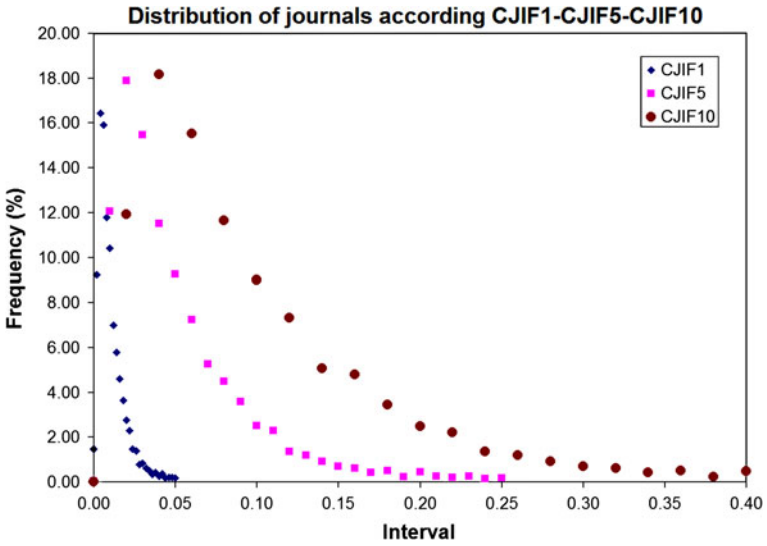

Fig. 1 Distribution of journals according to CJIF1, CJIF5 and CJIF10. To avoid the effect of extreme values, the figures include 98.7 % of journals (CJIF1), 98.8 % of journals (CJIF2) and 97.8 % (CJIF10)

highly skewed. As expected, journals benefit when citations are added, but this gains in JIF*n* are distributed in a similar way when *n* changes. Thus, it appears that no particular groups of journals experienced a notable increase in JIF when more citations were added.

As noted above, a given journal can be listed in more than one JCR group. When the effect of additional citations on rank order are calculated, we can expect different effects for the same journal in different groups. We accordingly studied the effect of adding *n* citations on the rank order of journals in different JCR groups by computing statistics for JCR groups separately. Note that in the tables, the total number of journals appears greater because many journals are listed in more than one JCR group.

Table 1 shows the percentage of journals in each JCR group whose rank order changed with JIF*n* ($n = 1, 2, \ldots 10$). In most JCR groups the percentage of journals that changed

their rank order when we computed different JIF*n* did not change in a linear fashion with *n* (the number of citations we added). In 31 JCR groups (about 18 % of the whole set), the addition of just 1 more citation to the number of citations used to compute the JIF changed the rank order for more than 25 % of journals in these JCR groups. The most extreme cases were the JCR groups History & Philosophy of Science (57.5 %), Mathematics, Applied (62.9 %) and Mathematics (74.3 %). There are 24 JCR groups (about 14 % in the whole set) in which no journal changed its rank order when we computed JIF1. These JCR groups contain lower numbers of journals (typically from 20 to 30). However, other JCR groups with similar numbers of journals experienced changes affecting more than a 10 % of journals. Thus, the size of the JCR group is not a determining factor for the absence of changes in rankings.

Figure 2 shows the association between the number of journals in each JCR group and the percentage of journals that changed their rank order when 1, 5 or 10 citations were added to compute the JIF. There was an obvious effect of the number of citations: more citations led to more changes.

A more important outcome than the percentage of journals that change their rank order in each JCR group is the magnitude of the changes. This result is important because the relative position within a JCR group is the main indicator usually used to compare journal ranks. As explained above, the variable CR*n* measured the change in rank for each journal with different values of *n*. We have studied the percentage of journals whose CR changed when JIF1, JIF5 and JIF10 were computed (Tables a–c, supplementary material). For example, in the case of JIF1 (i.e., when one citation was added; Table a-supplementary material), 86.7 % of journals in the Agriculture, Dairy & Animal Science group showed no change in rank position (CR0), whereas 11.1 % improved their rank by one position (CR1) and 2.2 % moved up in the rank by two positions (CR2).

In the case of $n = 1$ (i.e. when we added 1 citation to compute the JIF; Table a-supplementary material), there were only 18 JCR groups (about 10 %) in which 10 % or more of journals increased their rank by two or more positions. The largest changes involved the journals *Group Geom Dynam* and *Math Intell* (JCR group Mathematics). When just 1 citation was added, the former journal increased its JIF from 0.519 (position 119) to 0.556 (position 106). The JIF of the latter journal increased from 0.344 (position 169) to 0.375 (position 156). In the case of $n = 5$ (Table b-supplementary material), there were only 15 JCR groups (about 8.7 %) in which more than 50 % of journals increased their rank by two or more positions. In the case of $n = 10$ (Table c-supplementary material), there were 45 JCR groups (about 26 %) in which more of 50 % of journals increased their rank by two or more positions.

Table 2 shows the absolute number and percentage of journals according to the value of CR*n* (0, 1, 2, … 15 or more changes in rank position) when $n = 1, 2 \ldots 10$. As expected, the percentage of journals that did not experience changes in rank order decreased as *n* increased (Fig. 3). The percentage of journals that moved up by one position in rank order increased initially and then decreased slowly. The percentage of journals that moved up two or more positions increased as *n* increased. However, the increase in the percentage of journals tended asymptotically to stable values and the rate of increase decelerated (see Fig. 4). Thus, the decrease with *n* in the percentage of journals with $CRn = 0$ as *n* increased resulted in an increase in all percentages for CR*n* greater than CR1.

A different approach to study the effect on rank order of adding citations to calculate JIF*n* is to compute the minimum number of citations that a given journal needs to change its position. For example, consider the journal *J Comput Acoust* in the Acoustics group ($JIF0 = 0.585$). Two citations need to be added to obtain a $JIF2 = 0.623$, which is higher

Table 1 Percentage of journals that changed their rank in each JCR group when 1, 2, 3 to 10 citations were added to the number of citations that contribute to the JIF

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Acoustics	15.4	23.1	26.9	26.9	30.8	38.5	46.2	50.0	50.0	50.0	26
Agricultural Economics & Policy	11.1	11.1	11.1	11.1	33.3	33.3	44.4	44.4	44.4	44.4	9
Agricultural Engineering							11.1	11.1	11.1	11.1	9
Agriculture, Dairy & Animal Science	13.3	22.2	28.9	44.4	48.9	57.8	62.2	64.4	64.4	64.4	45
Agriculture, Multidisciplinary	22.9	37.1	42.9	45.7	51.4	54.3	62.9	62.9	68.6	68.6	35
Agronomy	20.4	32.7	36.7	44.9	49.0	57.1	57.1	63.3	67.3	69.4	49
Allergy		5.9	5.9	5.9	5.9	17.6	17.6	23.5	23.5	23.5	17
Anatomy & Morphology		11.8	11.8	23.5	29.4	29.4	29.4	35.3	35.3	47.1	17
Andrology											5
Anesthesiology		4.5	4.5	9.1	9.1	9.1	13.6	18.2	18.2	18.2	22
Astronomy & Astrophysics	10.4	14.6	16.7	20.8	27.1	27.1	27.1	31.3	37.5	41.7	48
Automation & Control Systems	20.8	32.1	37.7	41.5	45.3	54.7	56.6	64.2	67.9	71.7	53
Behavioral Sciences	10.6	21.3	27.7	31.9	34.0	36.2	42.6	44.7	46.8	48.9	47
Biochemical Research Methods	11.1	15.9	25.4	28.6	30.2	31.7	34.9	36.5	39.7	41.3	63
Biochemistry & Molecular Biology	24.9	38.3	47.6	53.5	58.0	62.5	65.8	67.3	69.9	74.0	269
Biodiversity Conservation	3.6	10.7	25.0	28.6	35.7	35.7	35.7	35.7	35.7	35.7	28
Biology	15.3	31.9	41.7	45.8	55.6	59.7	62.5	65.3	65.3	66.7	72
Biophysics	17.4	24.6	27.5	30.4	33.3	37.7	44.9	44.9	44.9	47.8	69
Biotechnology & Applied Microbiology	19.0	35.2	45.1	49.3	57.7	65.5	69.7	70.4	71.1	72.5	142
Cardiac & Cardiovascular Systems	6.5	15.6	18.2	20.8	23.4	27.3	32.5	36.4	39.0	41.6	77
Cell Biology	17.3	29.5	35.9	42.9	45.5	51.3	54.5	55.8	59.0	62.8	156
Chemistry, Analytical	12.9	20.0	25.7	28.6	32.9	41.4	42.9	47.1	47.1	47.1	70
Chemistry, Applied	16.7	25.0	35.0	41.7	45.0	51.7	53.3	56.7	60.0	63.3	60
Chemistry, Inorganic & Nuclear	7.0	9.3	9.3	11.6	16.3	18.6	20.9	20.9	27.9	32.6	43
Chemistry, Medicinal		9.8	9.8	12.2	17.1	22.0	26.8	29.3	29.3	29.3	41

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Chemistry, Multidisciplinary	16.5	28.3	34.6	39.4	42.5	48.0	52.8	58.3	60.6	61.4	127
Chemistry, Organic	10.9	14.5	14.5	21.8	25.5	29.1	29.1	32.7	38.2	38.2	55
Chemistry, Physical	14.3	20.5	26.8	32.1	37.5	43.8	46.4	50.0	51.8	52.7	112
Clinical Neurology	17.0	30.1	41.8	49.7	55.6	60.1	63.4	65.4	66.7	70.6	153
Computer Science, Artificial Intelligence	29.0	37.6	52.7	60.2	71.0	75.3	79.6	81.7	81.7	82.8	93
Computer Science, Cybernetics	5.9	5.9	5.9	5.9	17.6	17.6	23.5	23.5	23.5	29.4	17
Computer Science, Hardware & Architecture	17.8	20.0	26.7	33.3	37.8	44.4	46.7	57.8	64.4	66.7	45
Computer Science, Information Systems	31.6	46.9	59.2	68.4	75.5	77.6	80.6	81.6	82.7	83.7	98
Computer Science, Interdisciplinary Applications	35.1	53.2	64.9	71.3	72.3	75.5	76.6	77.7	80.9	80.9	94
Computer Science, Software Engineering	25.6	45.3	55.8	68.6	73.3	76.7	82.6	83.7	84.9	86.0	86
Computer Science, Theory & Methods	31.0	48.8	60.7	75.0	78.6	82.1	84.5	85.7	86.9	86.9	84
Construction & Building Technology	31.6	50.0	57.9	63.2	68.4	68.4	68.4	68.4	71.1	73.7	38
Critical Care Medicine			4.8	4.8	4.8	4.8	9.5	9.5	14.3	19.0	21
Crystallography		4.0	8.0	8.0	8.0	12.0	16.0	24.0	24.0	24.0	25
Dentistry, Oral Surgery & Medicine	18.2	29.1	41.8	50.9	56.4	60.0	61.8	65.5	65.5	67.3	55
Dermatology	9.3	20.9	20.9	25.6	32.6	37.2	41.9	48.8	51.2	51.2	43
Developmental Biology	10.5	15.8	26.3	28.9	28.9	31.6	31.6	36.8	39.5	42.1	38
Ecology	23.8	41.8	53.3	56.6	59.0	61.5	63.1	65.6	67.2	68.0	122
Education, Scientific Disciplines	4.2	20.8	33.3	41.7	41.7	41.7	45.8	50.0	50.0	54.2	24
Electrochemistry	4.5	9.1	9.1	9.1	9.1	9.1	9.1	13.6	18.2	22.7	22
Emergency Medicine								7.7	7.7	7.7	13
Endocrinology & Metabolism	11.8	22.6	26.9	29.0	33.3	37.6	43.0	44.1	47.3	48.4	93
Energy & Fuels	19.7	30.3	39.4	40.9	43.9	51.5	53.0	57.6	60.6	63.6	66
Engineering, Aerospace	24.0	24.0	28.0	32.0	36.0	52.0	60.0	64.0	68.0	68.0	25
Engineering, Biomedical	11.8	21.6	27.5	35.3	37.3	43.1	49.0	52.9	54.9	54.9	51

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Engineering, Chemical	31.9	41.6	58.4	63.7	66.4	69.9	77.0	78.8	79.6	79.6	113
Engineering, Civil	44.0	59.3	70.3	75.8	79.1	85.7	86.8	86.8	89.0	90.1	91
Engineering, Electrical & Electronic	40.0	52.9	60.4	65.3	70.2	74.2	76.4	79.1	80.9	82.7	225
Engineering, Environmental	10.5	21.1	31.6	34.2	34.2	36.8	39.5	42.1	47.4	47.4	38
Engineering, Geological	8.0	24.0	36.0	44.0	44.0	48.0	68.0	72.0	72.0	76.0	25
Engineering, Industrial	12.1	15.2	24.2	33.3	36.4	45.5	45.5	51.5	54.5	60.6	33
Engineering, Manufacturing	15.8	31.6	44.7	47.4	52.6	60.5	60.5	71.1	71.1	71.1	38
Engineering, Marine	14.3	14.3	14.3	28.6	28.6	28.6	28.6	42.9	42.9	42.9	7
Engineering, Mechanical	33.7	46.2	58.7	66.3	73.1	74.0	77.9	79.8	82.7	83.7	104
Engineering, Multidisciplinary	32.8	43.3	47.8	59.7	67.2	70.1	74.6	76.1	76.1	83.6	67
Engineering, Ocean	6.7	6.7	13.3	46.7	53.3	53.3	66.7	66.7	66.7	66.7	15
Engineering, Petroleum	29.2	37.5	41.7	54.2	54.2	58.3	66.7	66.7	70.8	70.8	24
Entomology	29.6	46.5	56.3	62.0	64.8	69.0	70.4	74.6	76.1	76.1	71
Environmental Sciences	27.6	50.9	61.3	69.3	71.2	73.6	74.2	75.5	78.5	78.5	163
Evolutionary Biology		2.7	16.2	18.9	24.3	27.0	27.0	27.0	32.4	37.8	37
Fisheries	10.0	15.0	25.0	40.0	45.0	50.0	60.0	62.5	67.5	67.5	40
Food Science & Technology	31.4	42.2	53.9	59.8	60.8	63.7	65.7	66.7	71.6	74.5	102
Forestry	20.5	35.9	43.6	46.2	51.3	56.4	61.5	66.7	69.2	71.8	39
Gastroenterology & Hepatology	7.3	10.9	12.7	14.5	20.0	20.0	21.8	23.6	29.1	29.1	55
Genetics & Heredity	18.4	29.4	37.5	41.2	48.5	55.1	57.4	61.0	66.2	66.9	136
Geochemistry & Geophysics	14.1	18.8	26.6	43.8	53.1	60.9	67.2	70.3	70.3	71.9	64
Geography, Physical	12.9	12.9	19.4	22.6	32.3	32.3	35.5	35.5	38.7	38.7	31
Geology	33.3	45.2	54.8	64.3	69.0	71.4	73.8	73.8	73.8	73.8	42
Geosciences, Multidisciplinary	35.9	55.6	66.2	72.5	75.4	76.8	78.9	78.9	80.3	83.8	142
Geriatrics & Gerontology	2.8	13.9	16.7	22.2	22.2	25.0	27.8	33.3	33.3	38.9	36

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Health Care Sciences & Services	19.4	32.3	41.9	51.6	56.5	58.1	61.3	62.9	67.7	75.8	62
Hematology	9.7	19.4	27.4	29.0	30.6	37.1	41.9	45.2	48.4	50.0	62
History & Philosophy of Science	57.5	75.0	77.5	80.0	85.0	85.0	87.5	90.0	90.0	92.5	40
Horticulture	8.7	26.1	34.8	34.8	43.5	43.5	43.5	52.2	52.2	56.5	23
Imaging Science & Photographic Technology									9.1	18.2	11
Immunology	13.4	20.2	32.8	40.3	44.5	48.7	50.4	54.6	58.0	58.0	119
Infectious Diseases	4.0	8.0	16.0	18.0	20.0	26.0	28.0	30.0	32.0	34.0	50
Instruments & Instrumentation	16.1	25.0	30.4	37.5	42.9	48.2	50.0	55.4	57.1	57.1	56
Integrative & Complementary Medicine	14.3	21.4	21.4	28.6	28.6	28.6	28.6	35.7	50.0	50.0	14
Limnology		5.3	21.1	31.6	31.6	31.6	31.6	42.1	47.4	52.6	19
Marine & Freshwater Biology	17.4	40.7	53.5	54.7	59.3	64.0	69.8	73.3	76.7	76.7	86
Materials Science, Biomaterials		5.3	5.3	5.3	10.5	10.5	10.5	10.5	15.8	15.8	19
Materials Science, Ceramics	12.5	16.7	16.7	20.8	25.0	33.3	41.7	41.7	41.7	41.7	24
Materials Science, Characterization & Testing	21.4	32.1	46.4	46.4	60.7	64.3	64.3	71.4	75.0	75.0	28
Materials Science, Coatings & Films	6.3	6.3	12.5	12.5	12.5	25.0	25.0	25.0	25.0	31.3	16
Materials Science, Composites		14.3	23.8	38.1	38.1	42.9	47.6	57.1	61.9	61.9	21
Materials Science, Multidisciplinary	34.6	44.5	51.3	57.1	63.9	67.0	68.6	70.2	72.3	73.8	191
Materials Science, Paper & Wood	16.7	27.8	33.3	44.4	44.4	50.0	50.0	50.0	50.0	50.0	18
Materials Science, Textiles	6.3	6.3	12.5	18.8	25.0	37.5	37.5	43.8	43.8	50.0	16
Mathematical & Computational Biology	3.4	17.2	24.1	31.0	37.9	41.4	44.8	44.8	48.3	55.2	29
Mathematics	74.3	84.1	87.9	91.1	92.5	93.9	94.4	95.3	95.3	95.8	214
Mathematics, Applied	62.9	75.4	81.7	87.4	88.6	90.3	90.9	92.0	92.6	92.6	175
Mathematics, Interdisciplinary Applications	32.0	54.7	65.3	70.7	73.3	77.3	78.7	82.7	85.3	85.3	75
Mechanics	36.6	52.7	58.0	66.1	72.3	78.6	78.6	81.3	83.0	84.8	112
Medical Ethics				14.3	14.3	14.3	14.3	28.6	28.6	28.6	7

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Medical Informatics		5.0	10.0	20.0	20.0	25.0	25.0	25.0	25.0	30.0	20
Medical Laboratory Technology		3.7	7.4	11.1	14.8	14.8	22.2	22.2	22.2	25.9	27
Medicine, General & Internal	21.5	29.9	34.6	43.0	43.9	50.5	53.3	54.2	55.1	59.8	107
Medicine, Legal	10.0	10.0	20.0	30.0	30.0	40.0	40.0	40.0	40.0	40.0	10
Medicine, Research & Experimental	13.4	26.8	31.7	36.6	43.9	47.6	51.2	52.4	54.9	57.3	82
Metallurgy & Metallurgical Engineering	23.8	39.7	49.2	61.9	65.1	68.3	68.3	74.6	76.2	79.4	63
Meteorology & Atmospheric Sciences	13.5	21.2	25.0	34.6	38.5	44.2	50.0	50.0	55.8	55.8	52
Microbiology	13.3	21.1	28.9	37.8	38.9	44.4	46.7	47.8	48.9	53.3	90
Microscopy	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	22.2	22.2	9
Mineralogy	24.0	32.0	32.0	40.0	40.0	48.0	64.0	64.0	64.0	64.0	25
Mining & Mineral Processing	25.0	25.0	31.3	43.8	50.0	56.3	56.3	62.5	62.5	62.5	16
Multidisciplinary Sciences	9.5	26.2	38.1	45.2	47.6	54.8	54.8	57.1	57.1	57.1	42
Mycology	10.5	21.1	21.1	26.3	26.3	26.3	26.3	26.3	31.6	36.8	19
Nanoscience & Nanotechnology	17.3	23.1	30.8	30.8	32.7	34.6	34.6	38.5	46.2	50.0	52
Neuroimaging					8.3	8.3	8.3	8.3	16.7	16.7	12
Neurosciences	25.3	41.9	50.2	56.7	60.8	63.1	65.4	70.5	74.2	76.5	217
Nuclear Science & Technology	6.7	23.3	26.7	33.3	36.7	36.7	40.0	46.7	46.7	53.3	30
Nursing	33.9	61.3	71.0	80.6	85.5	85.5	87.1	88.7	88.7	88.7	62
Nutrition & Dietetics	11.9	22.0	32.2	40.7	40.7	42.4	44.1	44.1	45.8	50.8	59
Obstetrics & Gynecology	14.8	26.2	31.1	32.8	36.1	44.3	49.2	52.5	57.4	62.3	61
Oceanography	16.0	22.0	32.0	40.0	46.0	50.0	54.0	54.0	54.0	58.0	50
Oncology	19.6	26.6	32.2	40.6	44.1	47.6	49.0	52.4	56.6	58.7	143
Operations Research & Management Science	32.8	48.4	59.4	65.6	70.3	75.0	76.6	78.1	79.7	82.8	64
Ophthalmology	8.3	12.5	22.9	22.9	25.0	33.3	39.6	41.7	47.9	50.0	48
Optics	10.9	17.2	34.4	37.5	40.6	45.3	48.4	59.4	59.4	60.9	64

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Ornithology	5.6	22.2	27.8	33.3	50.0	55.6	61.1	61.1	61.1	66.7	18
Orthopedics	8.2	20.4	26.5	32.7	36.7	38.8	40.8	42.9	49.0	49.0	49
Otorhinolaryngology	16.1	19.4	19.4	25.8	32.3	35.5	35.5	41.9	45.2	48.4	31
Paleontology	25.0	35.0	52.5	57.5	65.0	70.0	72.5	77.5	82.5	82.5	40
Parasitology		4.0	8.0	8.0	8.0	8.0	8.0	8.0	16.0	28.0	25
Pathology	8.8	19.1	27.9	32.4	36.8	44.1	50.0	51.5	55.9	60.3	68
Pediatrics	13.1	29.8	35.7	44.0	47.6	48.8	52.4	56.0	59.5	60.7	84
Peripheral Vascular Disease	7.1	14.3	17.9	19.6	25.0	28.6	35.7	37.5	39.3	42.9	56
Pharmacology & Pharmacy	23.1	38.0	49.1	55.6	62.5	67.1	71.8	74.5	78.7	80.6	216
Physics, Applied	20.2	21.3	30.9	33.0	40.4	42.6	44.7	46.8	50.0	51.1	94
Physics, Atomic, Molecular & Chemical	9.7	16.1	19.4	22.6	25.8	25.8	25.8	25.8	29.0	29.0	31
Physics, Condensed Matter	6.6	11.5	21.3	23.0	24.6	27.9	34.4	36.1	42.6	44.3	61
Physics, Fluids & Plasmas	3.8	7.7	19.2	23.1	23.1	23.1	26.9	30.8	34.6	38.5	26
Physics, Mathematical	8.7	23.9	30.4	37.0	41.3	43.5	50.0	50.0	50.0	50.0	46
Physics, Multidisciplinary	13.4	22.4	31.3	32.8	37.3	38.8	43.3	46.3	47.8	49.3	67
Physics, Nuclear	5.3	5.3	5.3	10.5	15.8	15.8	15.8	15.8	15.8	15.8	19
Physics, Particles & Fields	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	24
Physiology	9.5	18.9	23.0	27.0	31.1	33.8	41.9	44.6	47.3	51.4	74
Plant Sciences	34.9	47.4	57.9	65.1	68.4	71.7	74.3	77.6	78.3	80.9	152
Polymer Science	16.4	30.1	41.1	46.6	49.3	50.7	54.8	57.5	58.9	60.3	73
Psychiatry	9.0	20.0	28.0	42.0	46.0	52.0	55.0	58.0	62.0	63.0	100
Psychology	11.5	21.3	27.9	34.4	41.0	47.5	54.1	54.1	57.4	60.7	61
Psychology, Experimental											1
Public, Environmental & Occupational Health	21.9	29.5	39.0	46.7	51.4	54.3	59.0	63.8	67.6	68.6	105
Radiology, Nuclear Medicine & Medical Imaging	13.2	20.9	28.6	38.5	45.1	52.7	54.9	54.9	57.1	60.4	91

Table 1 continued

Group	%C1	%C2	%C3	%C4	%C5	%C6	%C7	%C8	%C9	%C10	N journals
Rehabilitation	3.6	14.3	25.0	28.6	32.1	35.7	42.9	46.4	57.1	60.7	28
Remote Sensing				13.3	13.3	13.3	20.0	20.0	20.0	26.7	15
Reproductive Biology	12.0	16.0	16.0	16.0	16.0	16.0	16.0	20.0	24.0	24.0	25
Respiratory System	2.6	5.1	10.3	15.4	17.9	23.1	23.1	25.6	25.6	30.8	39
Rheumatology		4.5	9.1	9.1	9.1	9.1	9.1	13.6	13.6	18.2	22
Robotics	7.1	21.4	21.4	21.4	21.4	21.4	35.7	35.7	42.9	42.9	14
Soil Science	12.9	25.8	25.8	35.5	41.9	41.9	41.9	41.9	41.9	54.8	31
Spectroscopy	7.7	17.9	23.1	25.6	30.8	33.3	33.3	38.5	41.0	46.2	39
Sport Sciences	29.6	42.3	53.5	57.7	63.4	71.8	73.2	74.6	77.5	80.3	71
Statistics & Probability	39.1	59.8	69.6	75.0	77.2	79.3	82.6	87.0	88.0	89.1	92
Substance Abuse	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	11
Surgery	21.8	38.8	45.6	53.1	57.8	62.6	66.0	68.7	72.1	72.1	147
Telecommunications	13.6	33.3	43.9	50.0	60.6	66.7	68.2	69.7	72.7	74.2	66
Thermodynamics	11.4	27.3	40.9	50.0	52.3	54.5	54.5	61.4	65.9	65.9	44
Toxicology	13.5	20.3	29.7	36.5	41.9	47.3	48.6	51.4	54.1	55.4	74
Transplantation		4.8	4.8	4.8	4.8	4.8	9.5	9.5	14.3	14.3	21
Transportation Science & Technology	4.3	17.4	30.4	39.1	43.5	47.8	52.2	52.2	60.9	65.2	23
Tropical Medicine	6.7	6.7	6.7	6.7	6.7	6.7	13.3	13.3	26.7	26.7	15
Urology & Nephrology	17.5	24.6	26.3	29.8	35.1	38.6	42.1	42.1	43.9	47.4	57
Veterinary Sciences	44.8	59.0	70.1	74.6	77.6	79.1	82.8	85.8	88.8	90.3	134
Virology		7.4	11.1	11.1	11.1	11.1	11.1	11.1	18.5	33.3	27
Water Resources	15.3	28.8	47.5	57.6	57.6	64.4	69.5	71.2	78.0	78.0	59
Zoology	42.7	62.9	71.8	78.2	80.6	82.3	83.1	83.9	87.1	87.1	124

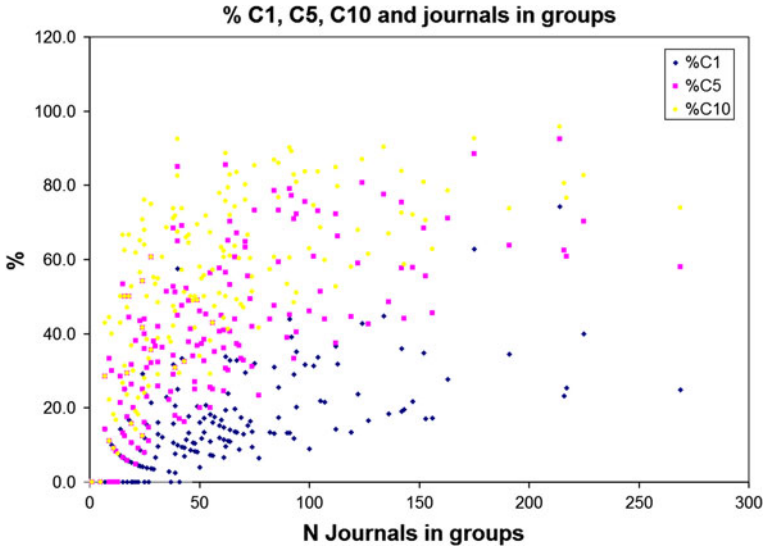

Fig. 2 Relationship between the number of journals in each JCR group and the percentage of journals that changed their rank when 1, 5 or 10 citations were added to compute the JIF

than the JIF0 of *Acoust Phys* + (JIF0 = 0.622). If we had added only 1 more citation, the JIF1 for *J Comput Acoust* would have been JIF1 = 0.604 (note that everything else equal remained equal, i.e., we compared the new JIF*n* for a given journal with the old JIF0 for all other journals). Thus, the minimum number of citations that *J Comput Acoust* would need to improve its rank position is 2. Similar calculations can be done for each journal in every JCR group. In 53 JCR groups (about 31 %), 50 % or more of the journals changed their rank position when 1–5 citations were added to the number used to compute the JIF. In contrast, in 63 JCR groups (about 36 %), 50 % or more of the journals did not change their rank position even after 10 citations were added (Table d-supplementary material). Here we include all journals that occupied the top position in each JCR group. These journals, by definition, cannot change their rank position.

One of the referees suggested that, given that the JIF distribution is very skewed, the low and middle ranges are much more sensible to changes then the top ones to the additional citations. To address this comment, we have examined the effect of adding different number of citations (1, 5, and 10) when considering different quartiles ($Q1$, $Q2$, $Q3$ and $Q4$). To avoid spurious results, we only considered groups having 50 or more journals ($n = 84$). We divided these journals in quartiles and we computed the mean of CR1, CR5 and CR10 for each group and quartile. The results are sometimes mixed, but, in general, journals in $Q2$, $Q3$ and $Q4$ showed higher values of CR, as could be expected (Table e-supplementary material).

Conclusions

In a previous paper one of us noted that an interesting research project would be to evaluate the effect of adding or removing citations and/or articles in the equation used to compute

Table 2 Absolute number and percentage of journals according the value of CRn (0, 1, 2, to 15 or more changes in rank) when $n = 1$, 2 to 10

Changes in rank	1	%	2	%	3	%	4	%	5	%	6	%	7	%	8	%	9	%	10	%
0	8,224	78.2	7,017	66.8	6,173	58.7	5,549	52.8	5,117	48.7	4,708	44.8	4,394	41.8	4,125	39.2	3,859	36.7	3,650	34.7
1	1,631	15.5	2,019	19.2	2,205	21.0	2,238	21.3	2,147	20.4	2,150	20.5	2,120	20.2	2,076	19.8	2,044	19.4	1,998	19.0
2	389	3.7	760	7.2	918	8.7	1,072	10.2	1,177	11.2	1,197	11.4	1,198	11.4	1,224	11.6	1,229	11.7	1,243	11.8
3	153	1.5	314	3.0	479	4.6	580	5.5	663	6.3	719	6.8	756	7.2	766	7.3	803	7.6	813	7.7
4	54	0.5	162	1.5	272	2.6	329	3.1	411	3.9	462	4.4	514	4.9	553	5.3	557	5.3	590	5.6
5	25	0.2	79	0.8	130	1.2	202	1.9	265	2.5	321	3.1	371	3.5	385	3.7	429	4.1	418	4.0
6	14	0.1	44	0.4	105	1.0	148	1.4	163	1.6	217	2.1	231	2.2	277	2.6	315	3.0	342	3.3
7	8	0.1	45	0.4	55	0.5	94	0.9	121	1.2	161	1.5	185	1.8	206	2.0	216	2.1	257	2.4
8	5	0.0	20	0.2	35	0.3	78	0.7	100	1.0	103	1.0	138	1.3	168	1.6	187	1.8	191	1.8
9	3	0.0	13	0.1	36	0.3	40	0.4	57	0.5	80	0.8	98	0.9	116	1.1	160	1.5	148	1.4
10	0	0.0	9	0.1	24	0.2	34	0.3	54	0.5	76	0.7	83	0.8	90	0.9	86	0.8	141	1.3
11	2	0.0	5	0.0	16	0.2	24	0.2	51	0.5	43	0.4	69	0.7	84	0.8	90	0.9	89	0.8
12	1	0.0	6	0.1	14	0.1	22	0.2	30	0.3	41	0.4	55	0.5	67	0.6	78	0.7	82	0.8
13	2	0.0	2	0.0	8	0.1	19	0.2	23	0.2	39	0.4	32	0.3	45	0.4	68	0.6	75	0.7
14	0	0.0	5	0.0	6	0.1	15	0.1	21	0.2	36	0.3	33	0.3	28	0.3	33	0.3	61	0.6
15	0	0.0	1	0.0	6	0.1	12	0.1	13	0.1	19	0.2	42	0.4	48	0.5	45	0.4	43	0.4
>15	0	0.0	10	0.1	29	0.3	55	0.5	98	0.9	139	1.3	192	1.8	253	2.4	312	3.0	370	3.5
Total	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100	10,511	100

Given that many journals were listed in more than one JCR group, each journal could experience different changes in rank depending on the JCR group in which it was included. Thus, the total number of journals was greater that in the whole JCR

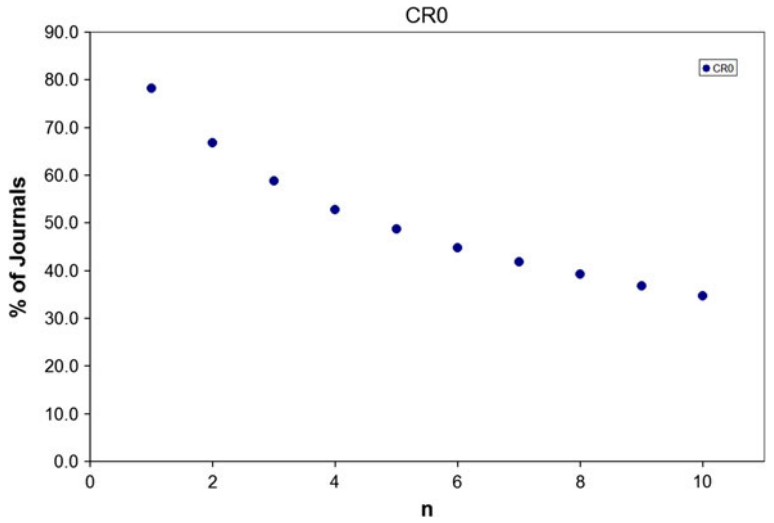

Fig. 3 % Journals that did not change their rank (CR0) when $n = 1$, 2 to 10 citations were added to the number used to compute the JIF

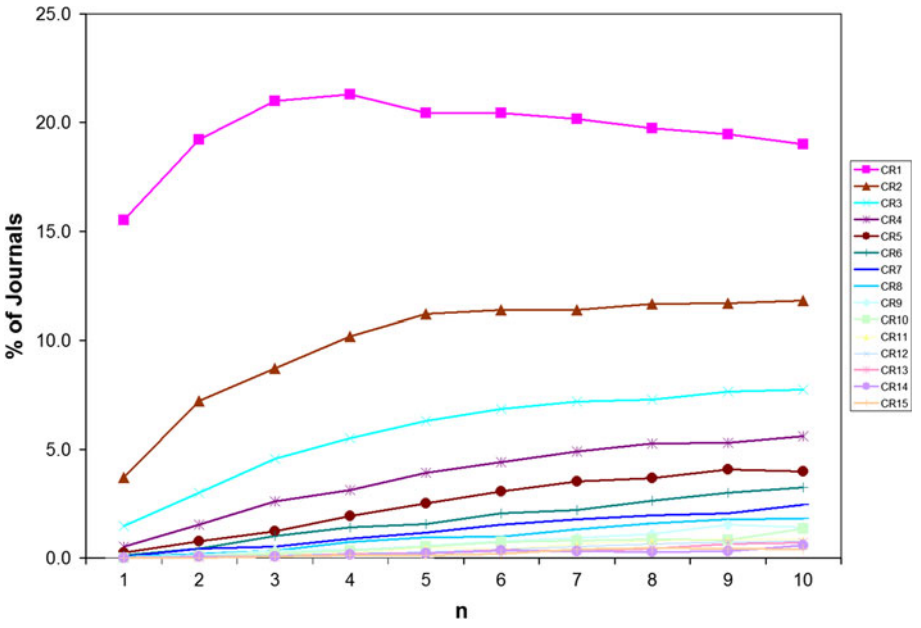

Fig. 4 % Journals that changed their rank by 1, 2, or more positions (CR1, CR2, …) when $n = 1$, 2, to 10 citations were added to the number used to compute the JIF

the JIF (Campanario 2012). The results of our research suggest that an increase of only 1 citation leads to small changes in the JIF in most journals, and therefore the effect on journal rankings within JCR groups is, in general, not very large. When we studied the

changes in journal rankings within JCR groups, it was clear that the effect of these changes was not very large.

When we added more citations, we found that the distribution of journals according to changes in their JIF were similar, but with different scales. Thus, there appeared to be no particular type of journals whose JIF increased when citations were added. Moreover, the percentage of journals whose rank position changed when we computed JIFs with additional citations did not change linearly with n, the number of additional citations added.

The effect of additional citations on the internal structure of rank orders within JCR groups obviously increased with n, the number of citations added. However, in general, the rank orders tended to be relatively stable after small increases in citations. In about one third of the JCR groups, about half of the journals changed their rank when to them 1–5 citations were added.

Journals often compete for citations in order to increase their JIF. One possible mechanism of manipulation is related with journal self-citations (Monastersky 2005; Yu et al. 2010). The results of our research suggest that the number of citations necessary to alter the rank order of journals within JCR groups is small for many journals, and that for most of them, more than 5 additional citations would be needed for the journal's rank order to change. When considering quartiles, more changes are observed, in general, in lower quartiles, given that JIF are very skewed. The journals in lower quartiles have more similar JIFs and small changes in citations can promote them to higher ranks that similar changes in citations in journals in the first quartile.

It should be keep in mind, however, that we studied changes in only one journal while keeping all other factors equal. When even small numbers of citations are added, the resulting changes in rank may interact to produce very different rank orders.

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References

Althouse, B. M., West, J. D., & Bergstrom, C. T. (2009). Differences in the impact factor across fields and over time. *Journal of the American Society for Information Science and Technology, 60*, 27–34.

Buela-Casal, G., & Zych, I. (2012). What do the scientists think about the impact factor? *Scientometrics, 92*, 281–292.

Campanario, J. M. (2012). Some research ideas on Journal Impact Factors as a crucial topic in science dynamics. *Scientometrics, 92*, 293–295.

Campanario, J. M. (in revision) The effect of citations on the significance of decimal places in the computation of journal impact factors.

Glänzel, W., & Moed, H. F. (2002). Journal impact measures in bibliometric research. *Scientometrics, 53*, 171–193.

Golubic, R., Rudes, M., Kovacic, N., Marusic, M., & Marusic, A. (2008). Calculating impact factor: How bibliographical classification of journal items affects the impact factor of large and small journals. *Science and Engineering Ethics, 14*, 41–49.

Monastersky, R. (2005). The number that's devouring science. *The Chronicle of Higher Education, 52*, A12.

Togia, A., & Tsigilis, N. (2006). Impact factor and education journals: A critical examination and analysis. *International Journal of Educational Research, 45*, 362–379.

Tsigilis, N., Grouios, G., Tsorbatzoudis, H., & Koidou, I. (2010). Impact factors of the sport sciences journals: Current trends, relative positions, and temporal stability. *European Journal of Sport Science, 10*, 81–90.

Vanclay, J. K. (2012). Impact factor: Outdated artefact or stepping-stone to journal certification? *Scientometrics, 92*, 211–238.

Vinkler, P. (2013). Would it be possible to increase the Hirsch-index, π-index or CDS-index by increasing the number of publications or citations only by unity? *Journal of Informetrics, 7*, 72–83.
Yu, G., Yang, D. H., & Liang, W. (2010). Reliability-based citation impact factor and the manipulation of impact factor. *Scientometrics, 83*, 259–270.