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Self-citation corrections for the Hirsch index

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Abstract – I propose to sharpen the index h, suggested by Hirsch as a useful index to characterize the scientific output of a researcher, by excluding the self-citations. Performing a self-experiment and also discussing in detail two anonymous data sets, it is shown that self-citations can significantly reduce the h index in contrast to Hirsch's expectations. This result is confirmed by an analysis of 13 further data sets.

Introduction. – About one year ago the physicist Hirsch [1] proposed an easily computable index h as an estimate of the visibility, importance, significance, and broad impact of a scientist's cumulative research contribution. This index h is defined as the highest number of papers of a scientist that received h or more citations. Of course, for many people "it is distasteful to reduce a lifetime's work to a number" [2]. For others h is an "elegantly simple" measure [3], which allows an easy comparison of the scientific achievement of a scientist in an unbiased way by a single number. As can be determined easily by ordering the publication list according to the number of citations which is for example possible using the Science Citation Index provided by Thomson ISI in the Web of Science (WoS) database, it has received immediate attention in the public [4] and the physics community [5–7] and is already widely recognized as a convenient measure in evaluations. Already a significant amount of literature in informetrics [8–13] has been dealing with this measure of visibility of a scientist. Different data sets have been evaluated to identify the most highly cited scientists in various fields [1,3,7,14]. A comparative study on committee peer review [15] of post-doctoral researchers in biomedicine suggested that the Hirsch index is indeed a promising (rough) measurement of the quality. The statistical correlation of the Hirsch index with standard bibliometric indicators and peer judgement was shown to be quite high for 147 chemistry research groups in the Netherlands [16]. A critical analysis of the Hirsch index of 187 evolutionary biologists and ecologists from the editorial boards of seven journals illustrates the risk of indiscriminate use of the index [2]. A quantitative investigation of the statistical reliability [6] has cast doubts on the accuracy and precision of the Hirsch index. Nevertheless the interest in this measure continues to grow [7–12,16–21].

It was shown [10] that the Hirsch index notion can be extended to the general framework of information production processes and that any system has a unique Hirsch index. Banks [21] has extended it to an index for scientific topics and compounds in order to identify hot topics and interesting materials. The Hirsch-Banks index is defined in analogy to h as the highest number of papers in a particular field or on a specific compound that received h or more citations. This extension has also received a lot of attention even beyond the scientific community, identifying nanotubes, nanowires and quantum dots as the most interesting topics in recent years. Other generalizations concern the comparison of entire research groups by their Hirsch index [16] and the utility for assessing the impact of journals [12,22].

When identifying hot topics, it is obvious that one will be dealing with a set of publications which are heavily cited within the field which means that they are probably most often cited by people working on the same topic, *i.e.* by the same set of people who have written these publications. However, when assessing the scientific achievement of an individual scientist, the analogous kind of citations within the data set, namely the self-citations should ideally not be included, because they are not reflecting the impact of a publication. Of course, self-citations increase the h index, but Hirsch has argued that the effect is relatively small and that the necessary corrections for h would involve only very few if any papers. An analysis of a group of scientists in ecology and evolution [2], however, showed an average decrease of 12.3%. In contrast, the Hirsch indices of 31 influential scientists in information science dropped only between zero and three, on average by 0.9, or 6.6%, when self-citations were excluded [3]. In the present investigation I demonstrate that the influence of self-citations on the Hirsch index can be drastic, in particular for younger scientists with a low Hirsch index. Three different ways to sharpen the Hirsch index will be proposed.

Database. – It is a rather time-consuming task to identify all self-citations. Because of self-interest and of the fact that it is relatively easy to check one's own publications and citations I first performed a self-experiment and investigated several ways to determine the self-citations by myself and by my co-authors. Excluding them, my Hirsch index dropped by 18%. Then I also analyzed the publications of a somewhat older colleague who is working in a more topical field in a mainstream area. In contrast, I also investigated the records of a somewhat younger colleague, working in a less attractive field, who has published fewer papers. Their Hirsch indices also dropped significantly by 13% and 46%, respectively.

Before analyzing the self-citations, one has to make sure that the database is correct. This concerns the usual difficulties, that different persons with the same name and same initials are found. The often suggested solution to check the affiliation is rather complicated when researchers are concerned who have changed between various places. Moreover, my own university is an example, why the correlation with the affiliation is often misleading, because we not only changed our name between faculty, department and institute; but also between Hochschule, Technical University, and University of Technology; and further from Karl-Marx-Stadt via Chemnitz-Zwickau to Chemnitz. Another problem in establishing the database is the possible different way of spelling names, which is particulary evident for the transliteration of, *e.g.*, Russian authors, or names which have changed, *e.g.*, by marriage. In principle, for the identification of the self-citations the same difficulties occur. However, it is quite unlikely that a manuscript is cited by a different scientist with the same name, so that this problem does not occur in practice. On the other hand, different ways of spelling an author's name or entirely different names of the same author can easily mask self-citations so that care should be taken in these cases. Of course, missing citations because of misspelled names cannot be avoided, because they do not show up at all in the search. The data sets used below have been carefully checked with respect to the mentioned difficulties. In my own case the WoS search yielded 754 results out of which only 268 were my own publications. The full list would give me a flattering, but wrong $h = 46$ instead of $h^{\mathrm{A}} = 27$. (The superscript is used to distinguish the different data sets.) The names of both colleagues whose publications are analyzed in detail below are not so common, so that in their cases the analysis was relatively easy, because nearly all papers which were found in the ISI

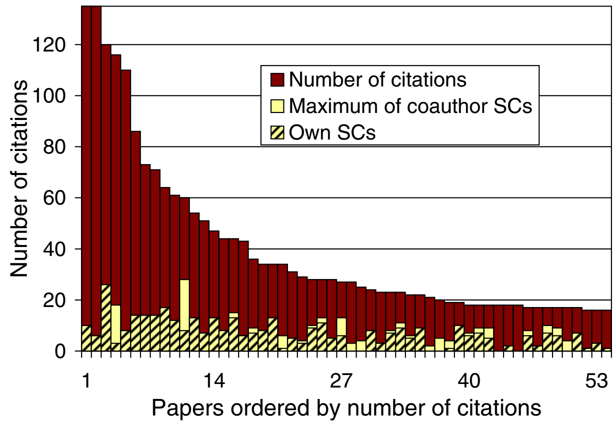

Fig. 1: (Colour on-line) Number of citations for my 54 most cited papers (dark grey/brown), own self-citations (hatched), and maximal number of citations by one of the co-authors including myself (light grey/yellow).

data base for their names were really published by these colleagues. For the set B with 282 papers I analyzed only the 131 publications with 10 or more citations and found just two which did not appear in this author's publication lists. For the set C I confirmed that 87 of the listed 91 papers should be attributed to the colleague. In both cases there was no influence on the Hirsch index.

Self-citations. – Before coming to the analysis of these data sets, let me comment on the question, why self-citations may appear. One reason is, that they are really needed in the manuscript in order to avoid repetition of previously described experimental setups, theoretical models, as well as results and conclusions which may be necessary for the discussion in a certain manuscript but need not be repeated in this manuscript. Such self-citations are of course completely legitimate. A second reason for self-citations is that probably everybody knows his own previous manuscripts best and therefore it is easier to refer to these own papers when a citation is required in a given context for a certain argument. This practice is already questionable, at least when the number of such self-citations is relatively high. The third reason for self-citations is certainly disreputable: Due to the ever-increasing number of evaluations which are based on citation counts, it is of course tempting to enhance one's citation count by referring to the own papers for this very purpose. The Hirsch index is vulnerable to such practice, because it is a single number which can be relatively easily enhanced by specifically citing those papers for which the citation count is close to but below the critical value h. For example, in my own case (see fig. 1) just one citation of my 28th paper would be sufficient to increase the Hirsch index. However, this paper happens to be first manuscript that I have ever co-authored so that its "limited period of popularity" [23] has long ended, it is also not a "sleeping beauty" [23] and therefore it is unlikely to be cited by somebody else. Therefore I would have to cite it myself, if I want this paper to have an effect on my Hirsch index.

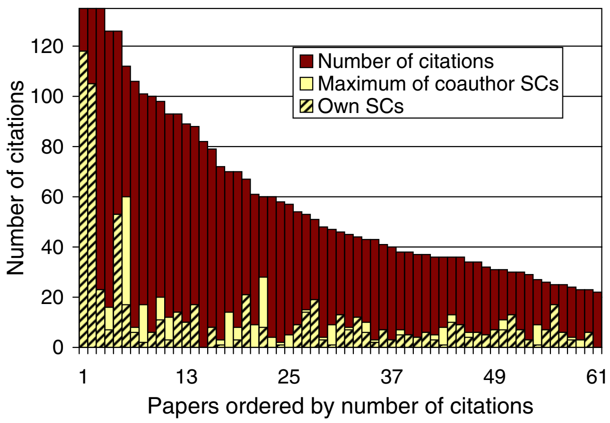

Fig. 2: (Colour on-line) Same as fig. 1 for the 61 most cited papers in data set B.

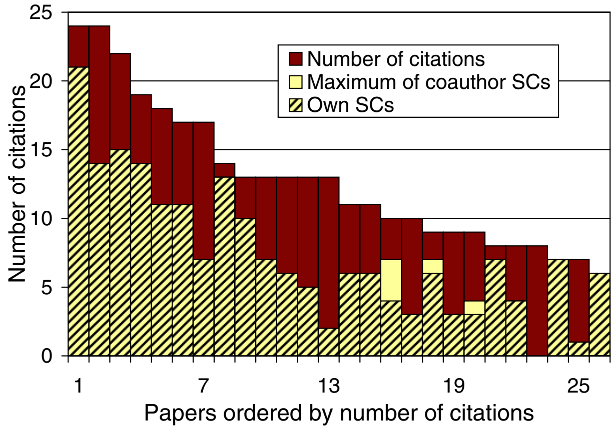

Fig. 3: (Colour on-line) Same as fig. 1 for the 26 most cited papers in data set C.

In the future, when the Hirsch index has become —as I expect— more popular, such manipulations might become more severe. In any case, even the perfectly legitimate self-citations mentioned above should not be included in any measure of scientific achievement, therefore the self-citations should be excluded.

SCCs **of the first kind:** h_o**.** – The problem is now how to identify self-citations. In the WoS search one can obtain the names of up to 100 citing authors for a given paper and how often these people cited the respective paper. Thus it is easy to identify how often somebody has cited his own paper. I call this the self-citation corrections (SCCs) of the first kind. The respective data are shown in figs. 1, 2, and 3 for the example data sets mentioned above. In my own case, see fig. 1, eight papers dropped below the critical value of $h^{\mathrm{A}}=27$, five of them even below the value $h_o^{\mathrm{A}}=24$. (The subscript is used to label the different SCCs.) Fortunately two manuscripts with the full citation count between 24 and 27 remained in that range even after the SCCs had been taken into account. Consequently, my Hirsch index was reduced only to $h_o^{\mathrm{A}}=h^{\mathrm{A}}-5+2=24$, not to $h^{\mathrm{A}}-8=19$. Of course, due to the strongly fluctuating number of self-citations, the publications have to be reordered by the number of citations after the SCCs have been taken into account. The respective result is shown in fig. 4, confirming $h_o^{\mathrm{A}}=24$. For the data set B in fig. 2, the SCCs are often drastic, like 53 self-citations for the fifth paper, but usually leaving still a significant number of other citations. Consequently the SCCs do not influence the Hirsch index very strongly, they lead to a reduction from $h^{\mathrm{B}}=38$ to $h_o^{\mathrm{B}}=34$, as shown in fig. 5. In the case C, however, the SCCs in fig. 3 are so significant, that the citation counts of all manuscripts fall below the value $h^{\mathrm{C}}=13$. However, 7 of these manuscripts have a corrected count of 7 or more citations, leading to the new $h_o^{\mathrm{C}}=7$. Out of the 12 manuscripts, which originally had between 7 and 12 citations, two remain in this range but cannot enhance the h_o^{C} value, as shown in fig. 6.

SCCs **of the second kind:** h_c**.** – Of course, if a paper is cited by one of the co-authors, such a citation should also not be taken into account. Using again the above-mentioned ISI list of citing authors for a particular publication, it is relatively easy to find the co-author with the highest number of citations for this particular publication. I call the reduction of the citation count by this number the SCCs of the second kind. For long author lists, on first sight the analysis appears to be not so straightforward, because the WoS summaries show at most 3 authors. However, the "Format for Print Page" displays all co-authors. In my own case, the number of citations for several manuscripts dropped significantly more by the SCCs of the second kind than by those of the first kind, as can also been deduced from fig. 1, in particular for order numbers 4, 11, 21, 27–29, 36–38, 50. Again a reordering of the manuscripts had to be performed, the result is included in fig. 4. The corresponding index h_c^{A}, which is corrected for the (co-)author with the most self-citations, can be determined from fig. 4 as $h_c^{\mathrm{A}}=23$. That means, that the SCCs of the second kind did further reduce my Hirsch index, but only slightly although the citation counts of several papers dropped. For the two colleagues, the respective data are also included in figs. 2, 5 and 3, 6, respectively. In case B, sometimes a co-author was an even more enthusiastic self-citer, see, *e.g.*, for the sixth paper in fig. 2, with 60 self-citations. Nevertheless, as this occurred again mostly for papers with a large citation count, the effect on the Hirsch index is small, it is reduced to $h_c^{\mathrm{B}}=33$. In the case C rarely a co-author was more enthusiastically citing his own manuscripts than the investigated author himself, therefore in this case the Hirsch index remains at the value $h_c^{\mathrm{C}}=h_o^{\mathrm{C}}=7$.

Analyzing the author list for the citations of a particular publication, it is straightforward to identify all co-authors as long as they appear among the set of 100 citing authors to which ISI displays are limited. Of course, the effort is significantly higher than for the SCCs of the second kind, because now one has to look for all co-author names in

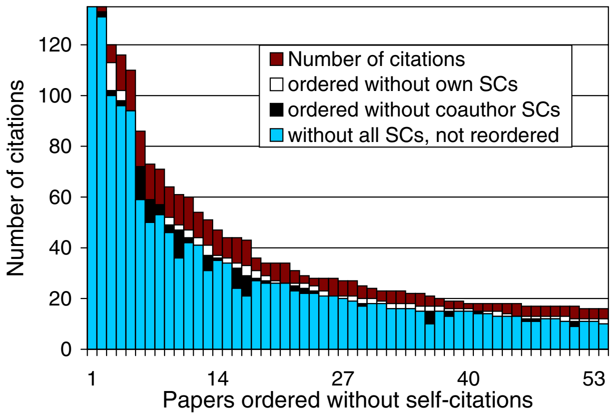

Fig. 4: (Colour on-line) Number of citations as in fig. 1 (dark grey/brown), without my own self-citations, reordered (white), without maximal number of any co-author self-citations, reordered (black), and without cumulative co-author self-citations, not reordered (medium grey/blue). Note that the latter histograms conceal the previous ones, so that in particular the columns of 2nd and 3rd kind often do not show up, because they are not different from the 3rd and/or 4th kind. The reordering is not restricted to the 54 papers in fig. 1 but comprises the full data set.

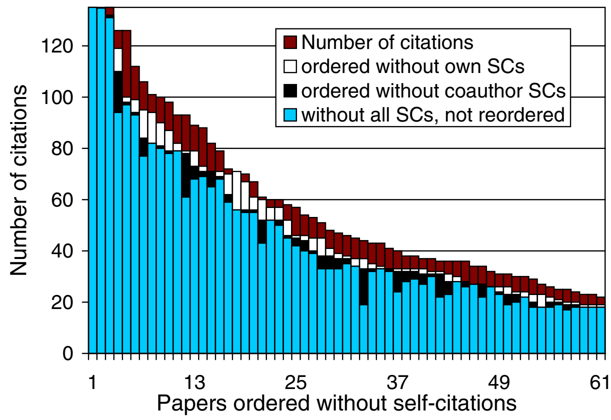

Fig. 5: (Colour on-line) Same as fig. 4, for data set B.

often long lists of citing authors; usually one has to check the complete lists, because some co-authors, *e.g.* typically PhD students never appear. Therefore I have performed this analysis completely only for my own publications and for the relatively small data set in fig. 3. Summing the self-citations of all co-authors of course overshoots the aim, because the counted self-citations are not just additive as two authors of a paper may have written another paper together, citing the first one, which would be counted as a self-citation for both co-authors. This overestimate can be so severe that it can lead to negative values for the citation count of papers which are heavily cited by several co-authors. Nevertheless I have analyzed the data in figs. 1 and 3 after subtracting the sum of all self-citations for each paper, resulting in a lower limit for the corrected Hirsch index of $h_l^{\mathrm{A}} = 20$ and $h_l^{\mathrm{C}} = 5$, respectively. For the data set B, the same analysis was performed only for the publications with 30 or more citations and yielded $h_l^{\mathrm{B}} = 29$. (Note that this result confirms that it is sufficient to analyze the publications with more than 29 citations.)

SCCs **of the third kind:** h_s**.** – The correct way of taking multiple co-author self-citations into account is obviously to check every citing paper for co-authorship. This yields the SCCs of the third kind. That requires an enormous amount of tedious work, which can be done relatively easy for one's own publications although it is still quite time consuming and error prone. Fortunately one can do this in the ISI citing author list by checking (ticking off) all co-author names and viewing the data, which gives a list and thus the number of cumulative self-citations of all co-authors. The results are included in figs. 4-6, and the analysis yields a reduction of the Hirsch index to the sharpened Hirsch index $h_s^{\mathrm{A}} = 22$, $h_s^{\mathrm{B}} = 33$, and $h_s^{\mathrm{C}} = 7$, respectively. It can be seen that the effect on the number of citations for many publications is zero compared to the SCCs of the second kind. Accordingly the reduction of the Hirsch index from h_c to h_s is small or zero. Therefore it is a rather safe assumption, that it is usually sufficient to perform this analysis only for those papers which are ranked in the vicinity of the index h_c defined above taking the SCCs of the second kind into account.

For the data set B of fig. 2 which is based on a large number of publications with a large number of citations and, most important for the amount of correlations, usually many co-authors, an analysis of the SCCs of the third kind for only the 22 publications with a citation count between 28 and 56, *i.e.*, between 85% and 170% of h_c^{B} appeared to be appropriate *a priori*. In retrospect, it would have been more than sufficient to determine the cumulative self-citations for the 10 papers with a citation count between h_c^{B} and about $1.2\,h_c^{\mathrm{B}}$, finding that although 3 out of these publications dropped below the value of $h_c^{\mathrm{B}} = 33$, the remaining were just sufficient to keep h_s^B at h_c^{B}. In fact, in this particular case, even an analysis of the 4 papers with a citation count of exactly h_c^{B} would have been enough. On the other hand, starting from the full citation counts (*i.e.* not taking first the SCCs of the second kind into account) one would have had to analyze at least the citations of 26 papers falling originally into the range between $0.85\,h^{\mathrm{B}}$ and $1.6\,h^{\mathrm{B}}$, in order to reach the correct $h_s^{\mathrm{B}} = 33$.

For my own case an analysis of the 15 publications between $0.85\,h_c^{\mathrm{A}}$ and $1.7\,h_c^{\mathrm{A}}$ yields the correct $h_s^{\mathrm{A}} = 22$, but a restriction to the 6 papers in the range between h_c^{A} and $1.2\,h_c^{\mathrm{A}}$ already misses one (the 17th in fig. 4) out of the 3 whose citation counts drop below h_c^{A}. Starting from the full citation counts, the range of $0.85\,h^{\mathrm{A}}$ to $1.7\,h^{\mathrm{A}}$ comprising 21 papers would have been just sufficient to determine h_s^{A} correctly.

For case C, the range $0.85\,h_c^{\mathrm{C}}$ to $1.7\,h_c^{\mathrm{C}}$ covers 13 publications including the ones most cited (after excluding the SCCs of the second kind). Therefore it is not surprising that this range is more than sufficient to determine h_s^{C}. In

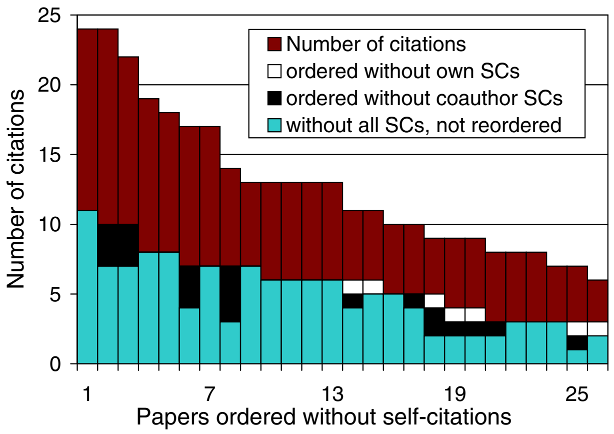

Fig. 6: (Colour on-line) Same as fig. 4, for data set C.

fact, also in this case an analysis of the 4 papers at h_c^{C} would have been enough to corroborate the value $h_s^{\mathrm{C}} = 7$, although 2 of these drop below h_s^{C}. On the other hand, starting from the original citation counts (*i.e.* without considering SCCs), even the range of $0.85\,h^{\mathrm{C}}$ to $1.7\,h^{\mathrm{C}}$ would have been insufficient for a correct analysis, one would have to start as low as $0.6\,h^{\mathrm{C}}$ and include also the most cited papers to obtain the correct value of h_s^{C}.

In table 1 the discussed values are compiled. The relative reduction from h to the sharpened Hirsch index h_s is considerable. Interestingly, the absolute decrease is nearly the same in all the above analyzed cases, namely 5 or 6, although very different publication and citation patterns distinguish the cases. It is therefore only a conjecture, when I infer that such an absolute reduction might by typical.

In order to test this conjecture, I have analyzed also a fourth data set D reflecting the achievements of a prominent scientist in La Jolla, again finding an absolute decrease of 5 which, however, amounts to a reduction of only 10%, because Hirsch's index is rather high. I have then investigated another 12 data sets of physicists which I know rather well so that it has been possible with a reasonable amount of effort to make sure that the data base is correct, in particular excluding publications of different persons with the same name and same initials, but on the other hand including publications with deviating spellings of the name (mainly due to missing second initials or an umlaut in the name). The obtained results are also included in table 1 as data sets E–P, sorted by the (original) Hitsch index. It turned out, that the absolute decrease from the original Hirsch index to the sharpened Hirsch index was 3 or 4 in most cases, thus being somewhat smaller than in the first 4 data sets. However, this is still significant, especially noting that the relative reduction is between 20 and 25% in most cases. Of course, due to the small values, a difference of 1 or 2 in the results should not be overvalued. However, as one example I note that the sharpened Hirsch index makes a distinction between data sets C and H much clearer than the original Hirsch index.

Table 1: Hirsch index without and with SCCs (data in sets A–D compiled August 2006, in sets E–P January 2007). The total number of publications, the highest citation count, and the relative reduction of the Hirsch index to the sharpened index are also given for each data set.

			Kind of SCCs				
			none	1st	2nd	3rd	
Data set	Total no.	Max. count	Hirsch index				
			h	h_o	h_c	h_s	$1-\frac{h_s}{h}$
A	268	178	27	24	23	22	18%
B	280	420	38	34	33	33	13%
C	86	24	13	7	7	7	46%
D	183	468	50	47	46	45	10%
E	322	73	20	17	16	16	20%
F	63	279	19	16	15	15	21%
G	66	149	15	14	13	12	20%
H	51	112	15	14	13	12	20%
I	72	55	14	11	11	10	29%
J	77	47	13	10	10	9	31%
K	47	108	13	13	11	11	15%
L	61	40	12	10	9	9	25%
M	46	53	12	11	10	10	17%
N	60	79	10	7	7	7	30%
O	44	41	10	9	8	8	20%
P	15	25	5	4	4	3	40%

On the other hand comparing data sets C and O, one finds from the original index the reasonable assumption that C is better than O. But the sharpened index suggests the opposite order. Data sets J and K are distinguishable by the sharpened index, but not by the original index.

Conclusion and outlook. – In conclusion, Hirsch's conjecture that usually only very few if any papers need to be dropped from the h count, if self-citations were taken into account, has been shown to be unrealistic. It may well be true for the prominent physicists that he has mentioned in his paper [1]. Roediger [24] has also argued about the self-citations that for "people with very high counts, they are not much of a problem." However, for the average scientist, this is not valid. I even believe it to be a good guess that for younger scientists with comparatively low Hirsch index, the influence of the SCCs is often relatively strong. Most of the data sets in table 1 are from younger scientists. But it is at this stage of the career where the Hirsch index is or will be probably most often used for the assessment of the scientific achievements of a scientist, be it for a promotion or for the comparison with competitors for an open position. One might argue from table 1 that the Hirsch index "only" renormalizes by about 20% due to SCCs and therefore remains to be a useful measure even with SCCs. For more prominent people this may be true, but for younger scientists the discussed deviations from the average reduction are important. Consequently, the Hirsch index should be used with reasonable care, and it would be good policy to take the SCCs into account. As mentioned above, it is straightforward and easy to determine the SCCs of the first kind and it is also relatively easy to calculate the corrections of the second kind. Taking the third kind, *i.e.*, the cumulative self-citations, into account is of course the method of choice, but it is rather difficult to execute, unless an automatic correlation between author lists and citing author lists can be performed.

Other corrections may also be reasonable in particular when comparing people working in different areas. It has already been observed by Hirsch [1] that citation patterns in different fields vary significantly. This was quantified [25] in terms of a scaling factor. Another correction with the (average) number of co-authors has been proposed [1,7,24,26] and a large impact especially in physics was found [7,26]. As the Hirsch index usually increases with the number of publications, it has been suggested to compare it with the average h for scientists in the same field and the same number of publications in order to detect those researchers who "clearly deviate from world standards" [25]. One should also be aware that the general search in the WoS data base does not take into account books, book chapters, or conference proceedings. For some fields these are less relevant, while in other fields they might be decisive for the impact of a scientist's research. Of course, it would also be interesting to investigate, how an individual's Hirsch index increases with time [1,17].

Based on a large data set of publications [27] the distribution of citations has been studied and a growing random network model was used to describe the citation statistics [28,29]. Citation patterns in a more homogeneous community in high-energy physics have also been analyzed and modelled in detail [30,31]. As already mentioned, when one wants to identify hot fields of research the citations within a certain community are of interest and should be measured, so that the self-citations might even have some value and need not necessarily be excluded. On the other hand, it is well known that there exists schools, sometimes also called citation cartels, whose members try to increase their visibility by citing mostly friends and family. It would be an interesting exercise to exclude citations within such a school from the determination of the Hirsch index. This can in principle be done by compiling a list of all co-authors with whom a certain scientist has published any paper and to exclude from the citation list of every manuscript every citation by anybody from this list. When this cumulative co-author list increases with time because new co-authors appear on the list, then the self-citation–corrected count of older manuscripts can be decreased and thus the index can also decrease with time, which is not possible due the SCCs discussed above, nor it is possible for the original proposal of Hirsch.

In any case, I believe that at least the own citations, *i.e.* the self-citations of the first kind, which can be most easily determined, should be excluded from any evaluation, because they can be most easily manipulated by the author. The temptation to increase one's Hirsch index oneself should be avoided, even though some journals explicitly suggest to their authors to cite themselves or other papers of the journal in order to increase the impact factor. This is of course understandable from their business point of view, but it is questionable from the scientific point of view.

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