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Modifying the Journal Impact Factor by Fractional Citation Weighting: the Audience Factor

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Abstract

A new approach to the field normalization of the classical journal impact factor is introduced called the audience factor. This approach takes into consideration the citing propensity of journals for a given cited journal, specifically the mean number of references of each citing journal, and fractionally weights the citations from those citing journals. Hence, the audience factor is a variant of a fractional citation counting scheme, but computed on the citing journal rather than citing article or disciplinary level, and in contrast to other cited-side normalization strategies is focused on the behaviour of the citing entities. A comparison with standard journal impact factors from Thomson Reuters shows a more diverse representation of fields within various quintiles of impact, significant movement in rankings for a number of individual journals, but nevertheless a high overall correlation with standard impact factors.

Introduction

Since the path-breaking work of Garfield (1972), the "impact factor" of scientific journals is regularly published in the Journal Citation Reports (JCR®) from Thomson Reuters. It has a strong influence on scientific publishing and, more controversially, on the evaluation of scientists, and is not without its misuses (for a review see Glaenzel & Moed, 2002).

The field dependence of reference and citation counts was recognized in the 1970s (e.g. Pinsky & Narin, 1976; Murugesan & Moravcsik, 1978; Garfield, 1979). A major determinant affecting impact is the ratio of cited to citing literature. The size of the literature (i.e., the number of articles) is itself linked to the size of the community by average productivity. Assuming a breakdown of science into separate fields and taking an insulated field without imports/exports of citations, we find that citing and citable literatures are analytically related through the growth rate, and the average impact defined in a certain time frame essentially depends on the propensity to cite, within this time frame, and on the growth rate. Garfield (1998) already noted that the size of the field was not a primary factor. In non-insulated fields where inter-fields exchanges occur, the citing and cited literatures or communities are different. In such a system the impact of "exporters of knowledge" are enhanced and conversely for importers.

The propensity to cite, and to cite in a given time frame (citation window, say 5 years), can be approximated by the average number of references per article in citing journals to cited articles 5 years old or less (deemed "active" references). This propensity depends both on general field features, such as the degree of specialization and social norms, and on particular features of the citing journal. A positive correlation is observed between average impact factor IF-5 (5 years) and the average number of references. The correlation coefficient and corresponding R-Square using 2006 data are shown in Table 1 (see also Biglu, 2008).

Table 1: Correlation of Average 5-year Impact Factor with Average Cited References

	All references	Active references
171 subject categories	Coef = .07 $p<0.0001$ R-square = .40	Coef = .23 $p<0.0001$ R-square = .81
8 large disciplines	Coef = .09 $p=0.01$ R-square = .68	Coef = .22 $p<0.0001$ R-square = .96

This effect partly explains the discrepancy of impact between, for example, fundamental biology and mathematics.

Various treatments of impact factors have been suggested in order to reduce the field-dependence. Most of them use an ex-post facto normalization of Garfield's IF (as published in Thomson's Journal Citation Report), as discussed in many articles (e.g. Sen, 1992; Marshakova-Shaikevitch, 1996; Vinkler, 2002; Schubert & Braun, 1996; Pudovkin & Garfield, 2004). Other corrections were proposed focusing on citation age (Sombatsompop et al., 2004; Rousseau, 2005), and journal self-citation (Fassoulaki et al.,2002). Radically different from ex-post normalized impacts is Pinsky & Narin's "influence weight" (1976), and reformulated in modern algorithms including Google’s page rank and Bergstrom’s eigenfactor (Bergstrom, 2007; Moya-Anegon, 2007; Palacio-Huerta & Volij, 2004; Kodrzycky & Yu, 2005, West et al.; discussion by Bollen et al., 2006). Depending on the settings, such influence measures can solve the citing-side issue. At the same time they tend to impose a magnification of the "natural" Matthew effect by the built-in feedback loop of multiple citing generations, but this can be mitigated by particular settings. Citing-side normalization , which like the impact factor considers only direct citations, has been practiced in bibliometrics for a long time at the article level ('fractionation of citations': Small & Sweeney, 1985, Zitt & Bassecoulard, 1994). In line with earlier suggestions about citing-side normalization (Zitt et al., 2005), here we investigate a journal-level citing-side normalization of impact factors.

Definition of the audience measure

Consider a source journal i(t) as a citing journal from some year t with references to other journals extending back in time as listed in the JCR. Let m_i (t,T) be the average number of references emitted by articles from i(t) in time window T(t)= [t-1..t-T]. This window defines the "active" references of I, other references being ignored. Now weight each emitted reference by a function of m_i (t,T). The simplest form is:

$w_i(t,T) = m_s(t,T) \ / \ m_i\ (t,T)$ **[1]**

where $m_s(t,T)$ is the average number of active references by articles in all source journals (all science).

This weight is greater for citing journals with shorter average lists of active references, for example a journal with scarce overall referencing or in a "slow" field - many examples can be found in mathematics. Then we sum the weighed citations emitted by each source journal i citing some specific cited journal j in time interval T. The definition of the audience factor AFT(t) follows that of impact factor IFT(t), except that weighted cites, instead of original cites, are used in the numerator.

$AFT_j\ (t) = \sum_i [\ w_i\ c_{ij}(t,T)\ ]\ \ / \ a_j(t,T)$ **[2]** where c_{ij} denotes the cites from journal i (emitted year t) to journal j (received by its articles dated within window T) and $a_j(T)$ the number of articles of journal j in window T. AF is obtained by introducing the weight w_i from **[1]** for cites from journal i. Except in the case of journals receiving most citations from their self-cites, the effect of the number of references in journal i and thus of the weighting w_i on the audience factor of the same journal (i) is diluted in the sense that the weighting is spread across many citing journals. Note that the impact factor IFT(t) is obtained by imposing $w_i = 1$.

In the following we take t=2006 and T=5. AF5 is more robust than AF2 but not calculable for new journals. Outliers with very low number of total references, often trade publications, could be spuriously over-weighted, especially through self-citation. Thus it appeared sensible to neutralize (by $w_i = 1$) source journals with less than 7 references per article in average. Emitting sources with insufficient information were neutralized in the same way. We also limited the ratio of maximum to minimum weights to x, i.e. $1/\sqrt{x} <= w <= \sqrt{x}$ in accordance with the distribution of references, to avoid excessive under-rating of review journals. This limitation induces a slight adjustment of the weighting scheme above. In this implementation we chose x=15.

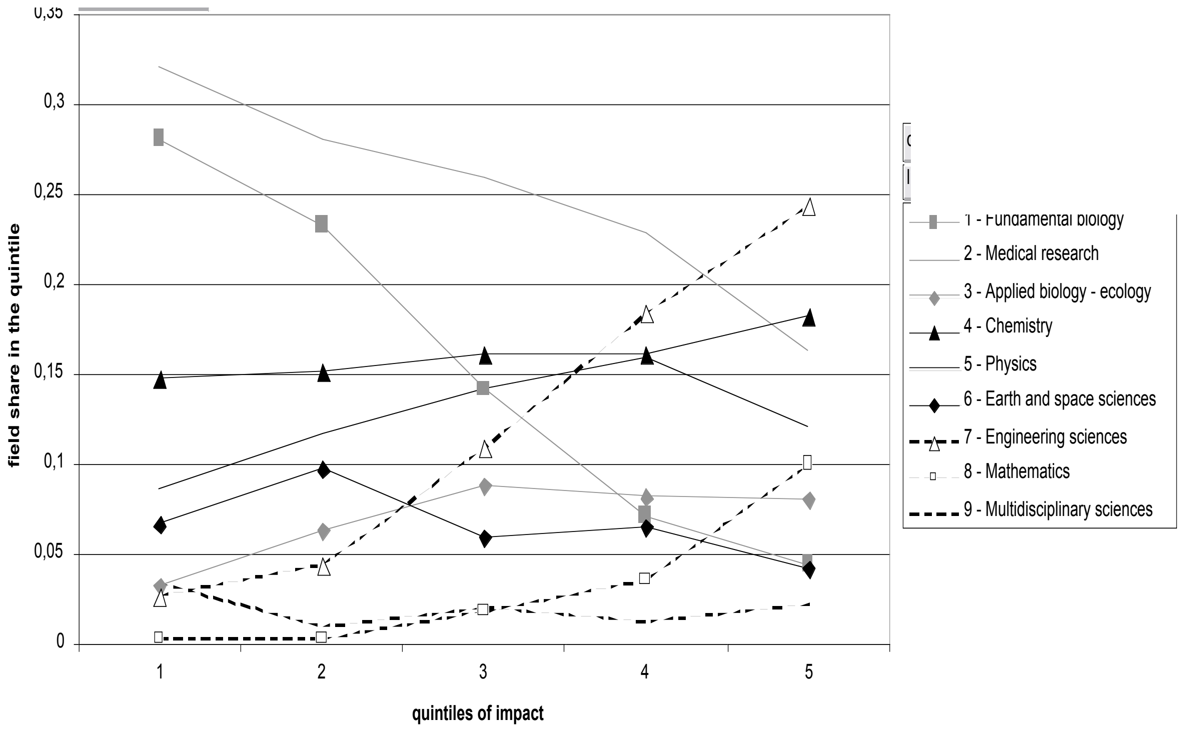
Results

AF5 does not put the IF5 ranking on its head. As expected, AF reduces the dominance of high IF journals and exhibits a less scattered distribution than IF. The correlation AF-IF remains high (with our options R-Square = 0.91 on log values; N=5,284), but this global convergence goes with strong differences from a cross-field perspective.

We distributed publications from all journals in quintiles based on journal visibility, using IF-5 (***fig. 1A) or AF-5 (***fig.1B). For example the first quintile on the left hand side collects the highest visibility articles, whatever the discipline. IF favors fundamental biology and also medical research, showing descending profiles, at the expense of engineering sciences and mathematics, which become more prominent at lower impact quintiles. AF shows much more balance, benefiting engineering science and mathematics, and to a lesser extent to physics. Medical sciences now show a quasi-neutral profile, and the advantage of fundamental biology is reduced but still present. Findings at the category code level (not shown) are similar.

Fig. 1A and B - quintiles of impact (A) and audience (B): distribution of disciplines

A: impact



disciplines: OST aggregations of Thomson Reuters subject categories.

B: audience

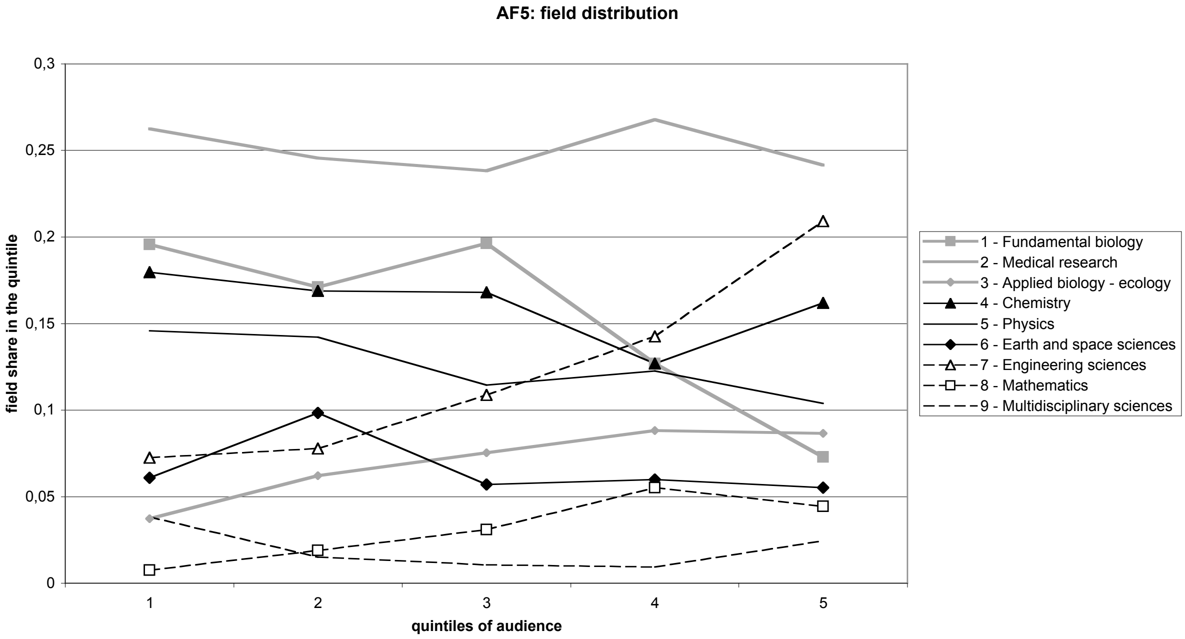


Table 2 contrasts the two measures for the top 22 journals by AF5. Further down the list the top mathematics journal, Bulletin of the American Mathematical Society, ranks 109 for AF5, and 501 for IF5.

Table 2 Top-ranked journals on AF5 and their rank on IF5

Title	IF5	AF5	rank(IF5)	rank(AF5)
REVIEWS OF MODERN PHYSICS	39.2	46.4	5	1
NEW ENGLAND JOURNAL OF MEDICINE	42.8	33.8	2	2
CA-A CANCER JOURNAL FOR CLINICIANS	40.8	33.1	3	3
ANNUAL REVIEW OF IMMUNOLOGY	52.2	30.5	1	4
MATERIALS SCIENCE & ENGINEERING R-REPORTS	20.0	26.7	27	5
CHEMICAL REVIEWS	28.9	26.6	14	6
PHYSIOLOGICAL REVIEWS	38.3	26.4	6	7
NATURE REVIEWS CANCER	39.9	25.4	4	8
SCIENCE	32.1	25.4	10	9
ANNUAL REVIEW OF BIOCHEMISTRY	38.2	24.1	7	10
NATURE	30.3	24.0	13	11
PROGRESS IN MATERIALS SCIENCE	14.4	21.2	55	12
NATURE REVIEWS MOLECULAR CELL BIOLOGY	34.1	20.7	8	13
NATURE REVIEWS IMMUNOLOGY	33.5	20.3	9	14
ANNUAL REVIEW OF NEUROSCIENCE	30.5	20.2	11	15
JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION	24.5	19.9	22	16
NATURE MEDICINE	30.4	19.5	12	17
NATURE REVIEWS NEUROSCIENCE	27.9	18.7	15	18
SURFACE SCIENCE REPORTS	17.0	18.5	35	19
ENDOCRINE REVIEWS	25.1	18.3	19	20
ADVANCES IN PHYSICS	15.1	18.0	48	21
LANCET	22.1	17.8	24	22

Conclusion

The audience factor, a weighted form of IF, controls for the differences of citing propensity and immediacy among fields. Its main features, in comparison with other types of measures, are shown in Table 3.

Table 3 - Methods of field normalization of impact

	Impact factor	Ex-post field-normalized IF	Audience factor	Eigenfactor and influence measures
propensity to cite	not normalized	jointly normalized*	normalized	normalized
Aging	not normalized (favors immediacy)		normalized	normalized
Growth	not normalized		not normalized	not normalized
across-fields citations exchanges	not normalized		not normalized	not normalized
enhancement of Matthew effect	No	no	No	yes*
sensitivity to field classification	No	yes*	No	no

* in typical proposals

In table 3 "not normalized" means that the corresponding effect is fully reflected in the measure.

Variants of the audience factor can be developed with other normalization bases, ranging from the article to the field. In a field-based normalization, the weight is determined by the average number of active references by citing article in the field, instead of the journal. An advantage over the journal basis is that the normalization would be almost insensitive to a possible overestimation of rating for a few non-scholarly journals where the low number of references reflects a low standard rather than a disciplinary norm. A shortcoming of the field-basis normalization is that the classification-independence property is lost. Note that in the limiting case where fields do not exchange citations and are in a steady state, the rationale of audience factor with field based normalization would be similar to the classical cited-side normalization also based on fields. Fractional citation approaches at various levels are promising for use in other citation analysis applications as well. A major question is whether citing-side normalization should stand alone or be embedded in influence measures reinforcing the "natural" Matthew effect.

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