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The excess-tail ratio: correcting journal impact factors for citation distributions

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Abstract

Despite their widespread adoption, journal Impact Factors suffer well-known drawbacks that limit their usefulness in accurately and fairly assessing scientific quality. Among these is the extreme variance and skewness in the citations to articles published by a given journal, which results in their sensitivity to a few highly cited articles, and enables many infrequently cited articles to "free-ride" on citations to these "skewed few." To address this problem, I adjust journal Impact Factors according to the relative citedness of the few highly cited articles in a journal's *h*-core (i.e., the h articles that receive at least h citations) and the many infrequently cited articles in its *h*-tail (i.e., those that receive fewer than h citations). I gauge the skew of a journal's citation distribution by e^2/t^2, the excess-tail ratio where e^2 captures excess citations above the h^2 citations received by a few highly cited *h*-core articles and t^2 captures surplus citations received by the many infrequently cited *h*-tail articles that fall below the *h*-core. I employ e^2/t^2 to adjust raw Impact Factors for 25 selected management and economics journals. The adjusted scores, $\widehat{IF}$, discriminate Impact Factors based on the shapes of journal citation distributions, leading to more accurate evaluation. I find $e^2/t^2 < 1$ (often << 1) for 23 of these journals to be consistent with an overstatement of their quality resulting from the sensitivity of Impact Factors to a few highly cited articles. Adjusted Impact Factors also yield distinctive and more consistent journal rankings over standard two-year and five-year time horizons. I conclude that the "excess-tail" ratio and $\widehat{IF}$ are a useful complement to journal Impact Factors, particularly given their increasing use in the evaluation of individual scholarly output.

Keywords: *h*-Index, *e*-Index, *h*-core, *h*-tail, excess-tail ratio, journal Impact Factor, $\widehat{IF}$

INTRODUCTION

Thompson Scientific is a database company that owns and publishes the Institute for Scientific Information (ISI) Web of Knowledge, which includes the Science Citation Index, the Social Science Citation Index, and the Journal Citation Reports. Central to the Journal Citation Reports are journal Impact Factors, which Thompson/ISI (1994) describes as "a systematic and objective means to critically evaluate the world's leading journals." The Impact Factor was devised in the 1960s by Eugene Garfield as a way to measure journal usage based on the mean number of citations per article within a specific period of time. A journal's Impact Factor is calculated by counting the number of current-year citations to articles published by the journal during the preceding two years and dividing this count by the number of articles the journal published in those two years. More recently, the ISI introduced a five-year Impact Factor (i.e., current-year citations to articles published by the journal during the preceding five years divided by the number of articles published in those years) to account for differences in the diffusion and obsolescence of ideas across fields.

Garfield's original idea was to sort journals by citation rates to aid in determining which to include in library collections (or indexes). Over the last decade, however, increasing electronic availability, along with aggressive marketing by Thomson Scientific, which acquired the ISI in 1992, has transformed the Impact Factor from a sorting device into a definitive quantitative rating of the quality of journals, of particular articles appearing in them and, by corollary, of the academics writing those articles. The journal Impact Factor is now in widespread use to evaluate researchers, serving central functions in academic hiring, peer review, and grant decisions—uses for which it was never intended and which Garfield (2006) himself has called misleading and inappropriate[1].

As a result, the Impact Factors of journals in which a researcher tends to publish are increasingly central to evaluations of his/her scholarly achievements. Indeed, the tendency has increasingly been to ascribe the Impact Factor of a journal to each article published within it. The veracity of such attributions rests on the assumption that a journal's Impact Factor is representative of its articles. For this to be true, the citedness of a journal's articles must follow a Gaussian distribution, with a narrow variance around the mean—that is, around its Impact Factor. It is well-known, however, that the distribution of citations to a journal's articles is highly skewed, with few articles near the mean. The skewness of article citedness is also problematic for Impact Factors as an index of journal quality because mean journal citedness is disproportionately influenced by a small number of highly cited articles. A small minority of articles, unrepresentative of the journal's publications, may thus be decisive in determining journal Impact Factors and resultant journal quality rankings (Baum, 2011).

To address this problem, I propose an adjustment for journal Impact Factors to account for the distribution of citations a journal receives. The adjustment is derived from two recent extensions to the *h*-index (Hirsch, 2005)[2]: e^2, which captures excess citations beyond the h^2 citations received by *h*-core articles (Zhang, 2009), and t^2, which captures surplus citations received by *h*-tail articles that fall below the *h*-core (Ye and Rousseau, 2010). A journal's citation distribution is gauged by the "excess-tail" ratio, e^2/ t^2, which indicates

1. In response, researchers increasingly emphasize publishing in journals with high Impact Factors rather than journals that might be more appropriate for their research, and may alter the kind of studies conducted to accommodate the predilections of such journals. This emphasis on Impact Factors has led some observers to comment that what a researcher contributes to our understanding is in danger of becoming less important than where it is published (Monastersky, 2005). This attention has also encouraged coercive editorial strategies to manipulate the system (Reedijk and Moed, 2008; Wilhite and Fong, 2012), as well as publisher policies to combat them (see, e.g., http://editorsupdate.elsevier.com/2012/06/impact-factor-ethics-for-editors/).

2. The *h*-index is the number of articles, *h*, that receive at least *h* citations; thus, the *h*-index is 25 for a journal that published 25 articles receiving at least 25 citations.

the relative citedness of the few highly cited articles comprising the journal's *h*-core and the many infrequently cited articles falling in its *h*-tail. The excess-tail ratio is used to compute $\widehat{IF}$ as *IF* x e^2/ t^2, where *IF* is the raw journal Impact Factor and $\widehat{IF}$ is the adjusted journal Impact Factor. Using the excess-tail ratio to adjust journal Impact Factors maintains the advantage of having a single index with which to evaluate journals, while incorporating important information on journal citation distributions.

I compute excess-tail ratios and $\widehat{IF}$ for a sample of 25 management and economics journals. I find $e^2/ t^2 < 1$ (often << 1) for 23 of the sample journals. These results are consistent with an overstatement of raw Impact Factors, attributable to their sensitivity to a few highly cited articles. I also find that $\widehat{IF}$ is more stable than raw Impact Factors across standard two- and five-year time horizons.

GAUGING JOURNAL CITATION DISTRIBUTION WITH THE EXCESS-TAIL RATIO

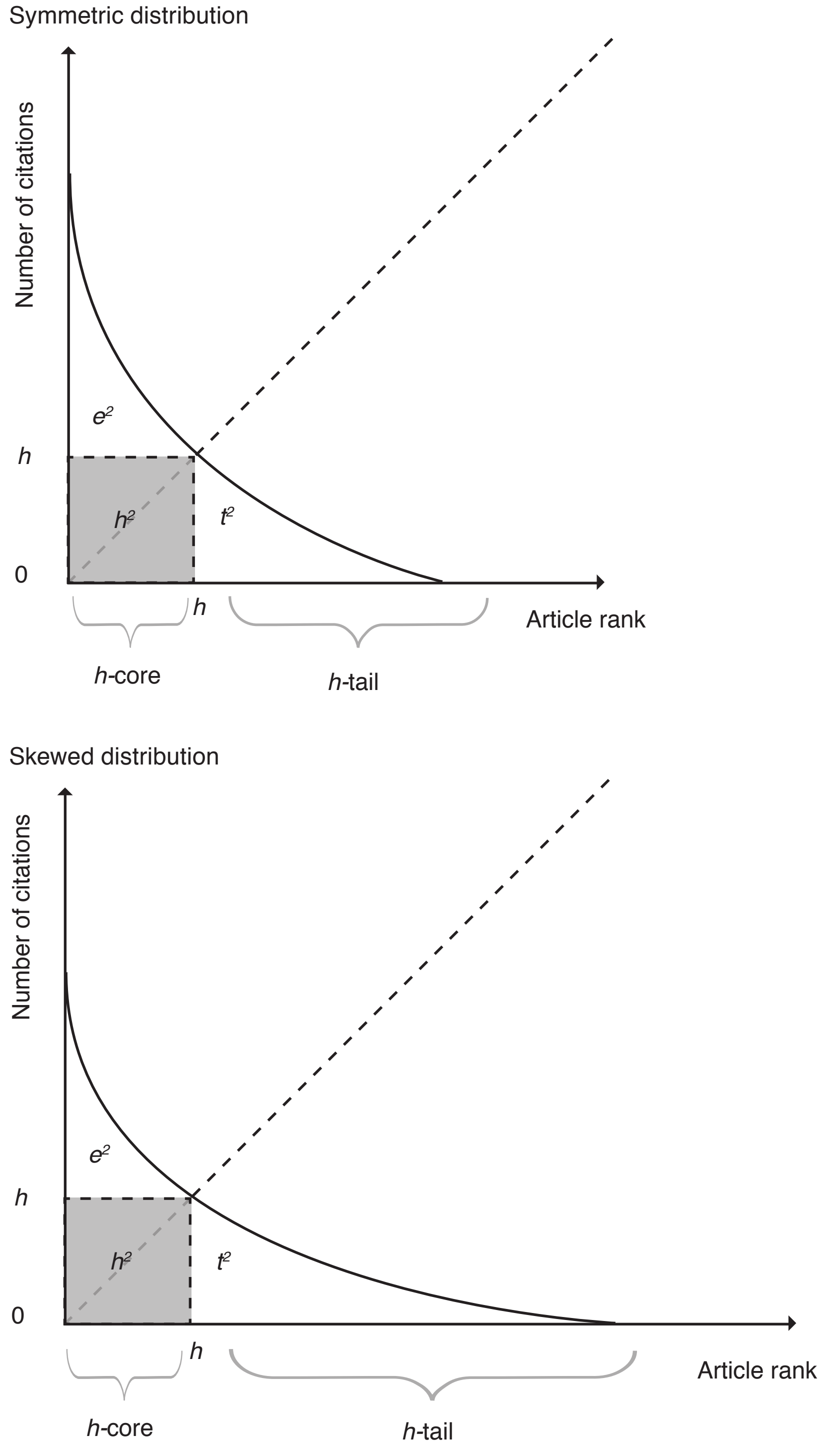
I gauge a journal's citation distribution using the ratio of, on the one hand, excess citations to the few highly cited articles in the journal's *h*-core to, on the other, surplus citations to the many infrequently-cited articles in the journal's *h*-tail. The *h*-index divides a journal's articles into two groups: the first group is the *h*-core, each having at least *h* citations during the period under study, and the second is the *h*-tail, each having at most *h*-1 citations.

The *h*-index, *h*-core and *h*-tail can be applied to many source–citation relations over many time windows (Ye and Rousseau, 2010). If there are *S* source articles and *C* citations, by definition the *h*-core consists of *h* articles and the *h*-tail consists of $S - h$ articles. The number of citations in the *h*-core, C_h, is a minimum of h^2 but has no upper limit. Zhang (2009) recently defined e^2, comprised of $C_h - h^2$ citations, to distinguish "excess" citations ignored by the *h*-index. The number of citations in the *h*-tail, t^2, ranges from 0 to $(S - h)(h - 1)$.

The relation between *h*-core and *h*-tail citations is illustrated in Figure 1, which represents the citedness of a journal's articles assuming a continuous citation function. In the figure, citations to the journal's *h*-core articles, C_h, are the sum of citations in the h^2 and e^2 areas. The t^2 area represents the surplus citations received by the journal's *h*-tail articles. The excess-tail ratio, e^2/ t^2, gauges a journal's citation distribution based on the ratio of excess *h*-core to surplus *h*-tail citations. When $e^2/ t^2 > 1$, citations tend to be excess citations to the few articles comprising a journal's *h*-core articles. When $e^2/ t^2 < 1$, citations tend to be surplus citations to the many articles comprising a journal's *h*-tail. Thus, the larger the ratio, the greater the extent to which a journal's citations reflect excess citations to its few most highly cited articles relative to surplus citations to its many infrequently cited articles[3].

3. Substituting $_{Ch}/ t^2$ for e^2/ t^2 gives identical results; the correlation between the two is $r = .996$ for the sample of journals examined below.

Figure 1. Geometric representation of e^2, t^2, *h,* and h^2



Adapted from Zhang (2009); Ye and Rousseau (2010)

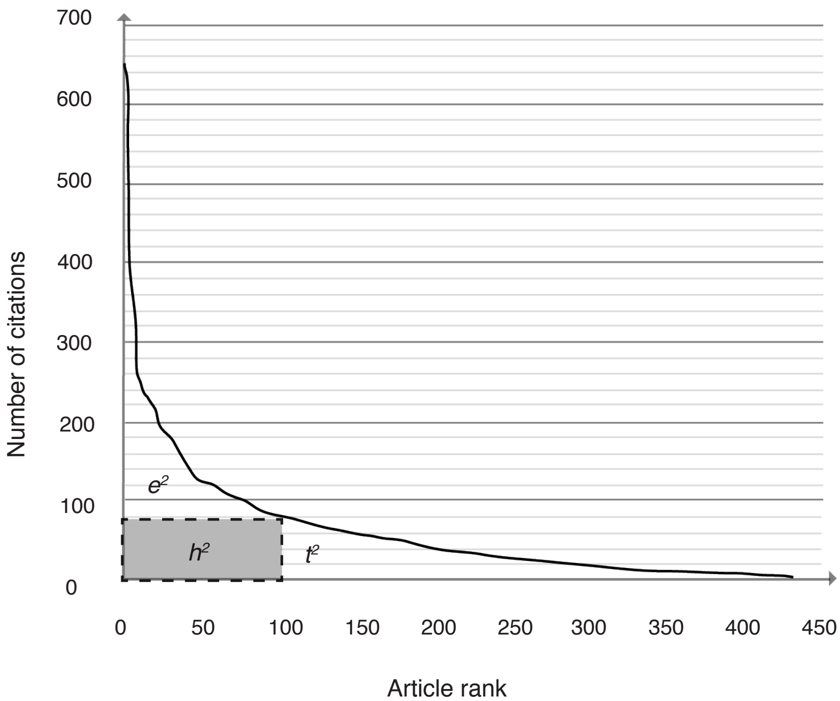
COMPARISON OF MANAGEMENT AND ECONOMICS JOURNALS

Publication data for the period 2000–2010, citation data for the period 2000–2011, and two- and five-year journal Impact Factors for 2010 were collected from Thomson Reuters/ISI Web of Knowledge for 25 management and economics journals[4]. Based on these data, I computed h, e^2, and t^2, as well as excess-tail ratios, and the adjusted journal Impact Factors, $\widehat{IF}$. Figure 2 provides an illustrative exemplar of the calculations for the Quarterly Journal of Economics, and Table 1 summarizes h, h^2, e^2, t^2 and the excess-tail ratios for all journals[5].

4. Using publication data for the period 2006–2010 and citation data for the period 2006–2011 results in lower values of e^2/t^2 for all journals, but does not otherwise alter the main findings or their implications.

5. Articles in a journal's h-tail may receive no citations, and so contribute nothing to t^2. When some h-tail articles go uncited, the excess-tail ratio may therefore overstate the "quality" of a journal's citations. To correct for this, t^2 can be substituted with the number of "reverse tail" citations rt^2; that is, the difference in the actual number of h-tail article citations and the number of h-tail citations if all h-tail articles received h citations. More formally, $rt^2 = t^2 – (S - h)(h - 1)$, which ranges from 0 to $(S - h)(h - 1)$. Because, for the 25 sample journals, the proportion of uncited h-tail articles is relatively small (mean =.058; min = .006; max = .171), the correlation between e^2/t^2 and e^2/rt^2 is 0.949, and the impact of this substitution on adjusted Impact Factors is negligible. Nevertheless, if the proportion of uncited h-tail articles is large, this substitution may be material.

Figure 2. Quarterly Journal of Economics citations, 2000-2010



$h = 90$
$h^2 = 8100$
$e^2 = 7921$
$t^2 = 11025$
$e^2/t^2 = 0.718$
2010 2yr $IF = 5.940$
2010 5yr $IF = 8.053$
2010 adj 2yr $\widehat{IF} = 4.268$
2010 adj 5yr $\widehat{IF} = 5.786$

Note: Ninety of the 457 articles published in the Quarterly Journal of Economics during the period 2000-2010 received at least 90 citations, giving h = 90 and $h^2 = 8,100$. The total number of citations received by these 90 "h-core" articles is, however, 16,021, yielding $e^2 = 16,021 – 8,100 = 7,921$. The total number of citations to the remaining 367 "h-tail" articles (each receiving < 90 citations) is 11,025, which gives t^2. Accordingly, $e^2/t^2 = 0.718$, indicating an inflated Impact Factor.

Table 1. Citation statistics and ratios for selected management and economics journals

Journal	***h***	***h***^{2}	***e***^{2}	***t***^{2}	***e***$^{2/}$ ***t***^{2}
Academy of Management Journal	106	11236	7225	20736	0.348
Academy of Management Review	85	7225	9025	9604	0.940
Administrative Science Quarterly	62	3844	4900	3364	1.457
American Economic Review	100	10000	8649	33489	0.258
Econometrica	74	5476	5929	11664	0.508
International Journal of Industrial Organization	29	841	625	4489	0.139
Journal of Economics & Management Strategy	27	729	576	1764	0.327
Journal of Economic Behavior & Organization	39	1521	900	6889	0.131
Journal of Economic Literature	58	3364	6084	2209	2.754
Journal of Financial Economics	81	6561	5625	16384	0.343
Journal of Finance	98	9604	6400	22801	0.281
Journal of Industrial Economics	32	1024	1156	1681	0.688
Journal of International Business Studies	61	3721	2401	9216	0.261
Journal of Law, Economics, & Organization	27	729	576	1521	0.379
Journal of Management	69	4761	4624	8100	0.571
Journal of Management Studies	55	3025	1849	9604	0.193
Journal of Political Economics	69	4761	3600	7921	0.454
Management Science	88	7744	7225	23409	0.309
Organization Science	76	5776	7225	10816	0.668
Organization Studies	48	2304	1600	6889	0.232
Quarterly Journal of Economics	90	8100	7921	11025	0.718
Review of Economics & Statistics	57	3249	2916	10000	0.292
Review of Economic Studies	53	2809	2116	6084	0.348
Review of Financial Studies	54	2916	2704	8464	0.319
Strategic Management Journal	96	9216	11025	17956	0.614

With two exceptions (Administrative Science Quarterly and Journal of Economic Literature), surplus *h*-tail citations exceed excess *h*-core citations, resulting in an excess-tail below 1 and for many journals << 1. Among the sample journals, modal citations thus tend to be citations to infrequently cited *h*-tail articles. As a result, a journal's $\widehat{IF}$ is generally smaller (and often significantly so) than its raw Impact Factor (Table 2). This result is consistent with raw journal Impact Factors being inflated by a few highly cited articles in a journal's *h*-core, when citations are more typically to one of a larger number of infrequently cited articles in the journal's *h*-tail[6].

6. The excess-tail ratio, e^2/t^2, can also be used to adjust the *h*-index itself, improving its ability to discriminate the shapes of citation distributions similarly (Zhang 2013).

Table 2. Raw and adjusted impact factors and rankings for selected management and economics journals

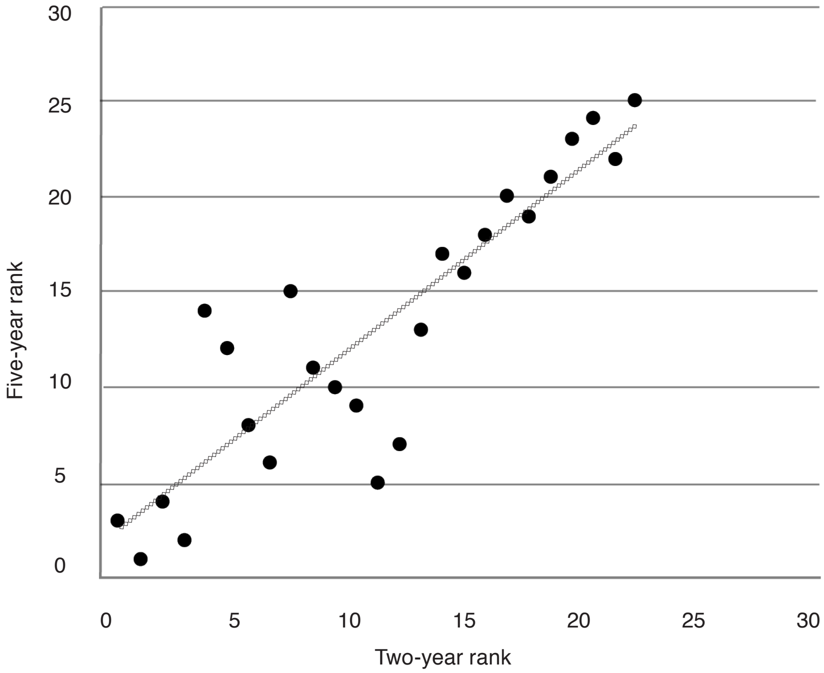
	Two-year		Five-year		Adj. two-year		Adj. five-year	
Journal	***IF***	**Rank**	***IF***	**Rank**	$\widehat{IF}$	**Rank**	$\widehat{IF}$	**Rank**
Academy of Management Journal	5.250	4	10.779	2	1.829	9	3.756	7
Academy of Management Review	6.720	2	11.657	1	6.315	2	10.954	2
Administrative Science Quarterly	3.683	13	7.359	5	5.365	3	10.719	3
American Economic Review	3.150	16	4.278	17	0.814	17	1.105	19
Econometrica	3.185	15	5.330	13	1.619	10	2.709	10
International Journal of Industrial Organization	0.731	25	1.247	25	0.102	25	0.174	25
Journal of Economics & Management Strategy	1.123	22	1.656	23	0.367	23	0.541	23
Journal of Economic Behavior & Organization	0.924	23	1.355	24	0.121	24	0.177	24
Journal of Economic Literature	7.432	1	8.076	3	20.469	1	22.243	1
Journal of Financial Economics	3.810	10	5.631	11	1.308	12	1.933	11
Journal of Finance	4.141	7	6.529	8	1.162	13	1.833	12
Journal of Industrial Economics	0.795	24	1.678	22	0.547	21	1.154	18
Journal of International Business Studies	4.148	6	5.539	12	1.081	14	1.443	15
Journal of Law, Economics, & Organization	1.595	21	2.172	21	0.604	20	0.823	22
Journal of Management	3.758	12	6.210	9	2.145	7	3.545	8
Journal of Management Studies	3.817	9	4.684	15	0.735	18	0.902	20
Journal of Political Economics	4.065	8	6.896	6	1.847	8	3.134	9
Management Science	2.221	20	3.966	19	0.685	19	1.224	17
Organization Science	3.800	11	5.838	10	2.538	5	3.900	6
Organization Studies	2.339	19	3.590	20	0.543	22	0.834	21
Quarterly Journal of Economics	5.940	3	8.053	4	4.268	4	5.786	4
Review of Economics & Statistics	3.113	17	4.300	16	0.908	16	1.254	16
Review of Economic Studies	2.883	18	4.163	18	1.003	15	1.448	14
Review of Financial Studies	4.602	5	5.016	14	1.470	11	1.602	13
Strategic Management Journal	3.583	14	6.818	7	2.200	6	4.186	5

Note: $\widehat{IF} = IF \times e^2 / t^2$

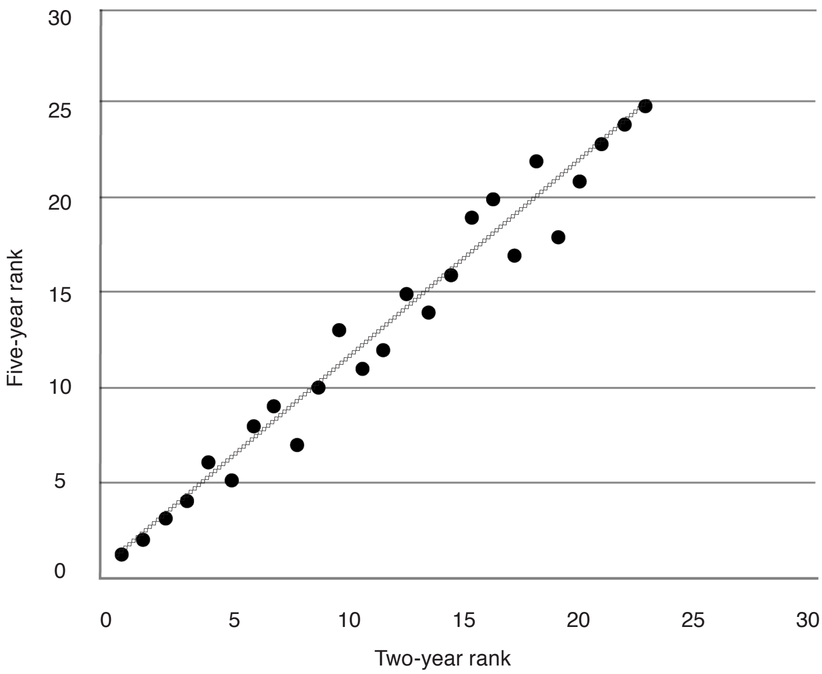
After making these adjustments the relative ranks of the journals shift, and sometimes substantially, as illustrated in Table 2. The lower a journal is ranked based on $\widehat{IF}$ relative to its raw Impact Factor, the greater the initial overstatement of its impact due to the sensitivity of its raw Impact Factor to a few highly cited *h*-core articles relative to the mass of infrequently cited *h*-tail articles. As illustrated in Figure 3, the correlation between two- and five-year rankings is substantially larger for $\widehat{IF}$ (r = 0.98) than for raw Impact Factors (r = 0.88). $\widehat{IF}$ is thus more consistent over different citation time horizons, particularly among higher-ranking journals.

Figure 3. Correlation between two- and five-year raw and adjusted journal Impact Factors

Raw Impact Factors (IF)



Adjusted Impact Factors ($\widehat{IF}$)



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CONCLUSION

As a measure of research quality, journal Impact Factors are problematic. The tendency to attach the same value to each article published in a given journal masks extreme variability in article citedness, and permits a journal's many infrequently cited articles—and the journal itself—to free-ride on the journal's few highly cited articles, which are principal in determining the journal's Impact Factor (Baum, 2011). I propose a correction for this problem whereby a journal's raw Impact Factor is adjusted to account for its citation distribution, which is gauged by the ratio of its excess *h*-core to surplus *h*-tail citations. This excess-tail ratio captures the extent to which the journal's citations are centered on the more or less frequently cited articles, and thus the more or less influential articles it publishes.

I employ the excess-tail ratio to recalibrate Impact Factors for 25 selected journals in management and economics. The excess-tail ratio is less than 1 (and often $<< 1$) for all but two sample journals. This is consistent with an overstatement of raw journal Impact Factors resulting from their sensitivity to small numbers of highly cited articles, and an inability to discriminate the shapes of the underlying journal citation distributions. Thus, while journal Impact Factors in management and economics are driven by citations to the journals' small number of influential *h*-core articles, more typically their citations are to one of the large number of infrequently cited *h*-tail articles they publish. Moreover, adjusted Impact Factors ($\widehat{IF}$) produce rankings that differ (often substantially) from the raw rankings, and are more consistent across two- and five-year time horizons.

The excess-tail ratio and $\widehat{IF}$ thus appear to provide useful complements to journal Impact Factors in assessing journal impact and quality, particularly given the increasing use of journal Impact Factors in the evaluation of individual scholarly output. Journal Impact Factors adjusted by these ratios carry additional information derived from journal citation distributions. As a result, $\widehat{IF}$ would appear to afford a more accurate single-number metric for the evaluation of journals and the authors who publish in them.

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