

# Why do statistics journals have low impact factors?

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In this paper, we answer the question why statistics journals get lower impact factors than journals in other disciplines. We analyze diffusion patterns of papers in several journals in various academic fields. To obtain insights into the diffusion of the citation counts of the papers, the data are analysed with the Bass model, leading to values for the time-to-peak that can be used to compare the speeds of diffusion paper citations of the different disciplines. Estimation results show that for statistics journals, it takes significantly more years to reach their peak. To further investigate diffusion, we also compute the percentages of the total number of citations a paper has after 2 or 3 years. Again, it appears that statistics journals have slower citation diffusion than journals in other disciplines. We conclude with some suggestions to reduce this disparity.

*Keywords and Phrases:* Impact factors, citations, diffusion models.

## 1 Introduction

For scientific journals, the impact factor (IF) is one of the most used indicators to gauge which journals are most influential. IFs have received a lot of attention in academic literature. Several authors have criticized the use of IFs, for instance HERNÁN (2008), REEDIJK and MOED (2008), KOSTOFF (1998) and SEGLEN (1997). Some of the criticism concerns the fact that it might be possible to manipulate IFs, for instance by encouraging self-citations. Moreover, some journals or reports are not in the index, resulting in missing citations. Finally, citations may be positive or negative (e.g. indicating that a paper contained flaws), so that being cited is not necessarily a good thing. In spite of these criticisms, IFs are still the most widely used indicators of the impact of journals.

The Thomson Institute for Scientific Information (ISI) computes the IF as a ratio that is defined as follows. The numerator is the number of citations in the current year to all items published in a journal in the previous 2 years. The denominator is the number of substantive articles (usually articles, reviews, proceedings or notes;

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not editorials and Letters-to-the-editor) published in the same 2 years in the same journal. For the currently (October 2008) available IFs, this amounts to the following. The numerator is the number of times articles published in 2005 and 2006 were cited in indexed journals during 2007. The denominator is the number of substantive articles published in 2005 and 2006 in the same journal. The 2007 IF is the ratio of these two numbers. In general, the 2007 IF is actually published in 2008, because it cannot be calculated until all of the 2007 publications have been received. The currently available IFs are indeed those for 2007, and became available on 17 June 2008.

When inspecting the Journal Citation Reports (JCR) by the Institute of Scientific Information (<http://isiknowledge.com/jcr>, 1 October 2008), one can find substantial variation across journals in the 2007 IFs. The journals in the top 10 vary from 69.03 (*CA: A Cancer Journal for Clinicians*) to 28.75 (*Nature*). The average IF in the top 500 equals 8.4. However, statistics journals rank considerably lower. Their IFs are below 3, with *Journal of the Royal Statistical Society Series B-Statistical Methodology* scoring the highest number with 2.210. This journal is ranked at place 1600. In Table 1, we show the highest scoring statistics journals.

The definition of the IF implies that in order to achieve a high number, it is important for journals to have their papers cited quickly and often. Another way to look at this is to say that editors would like to see their papers achieve quick diffusion, so as to give their journal more prestige through better IFs. If diffusion happens quickly, that is, many citations are obtained in the first few years after publication, the journal will benefit with a high IF.

Recently, an increase in attention for the diffusion of scientific papers can be observed. For instance, FOK and FRANSES (2007) find that the speed of diffusion of articles in *Econometrica* and *Journal of Econometrics* depends on certain characteristics of the paper like the number of authors and the number of pages. This dependence appeared to possibly change over the years. CONTRERAS, EDWARDS and WIZALA (2006) estimate a logistic diffusion model per discipline for the number of citations. Their approach allows estimating a so-called current impact factor (CIF) as well as a long-term impact factor, which represents the value to which the cumulative impact would converge (M). The ratio M/CIF measures how fast-or slow-moving are the different fields; the higher the ratio, the slower the field. There appears to be substantial difference in this ratio. In their analysis, CONTRERAS *et al.* do not include the academic field of our interest, namely statistics. Furthermore, the

Table 1. 2007 impact factors for statistics journals.

IF rank	Statistics journal	IF
1600	Journal of the Royal Statistical Society Series B-Statistical Methodology	2.210
1741	Journal of the American Statistical Association	2.086
1906	Annals of statistics	1.944
2326	Journal of the Royal Statistical Society Series A-Statistics in Society	1.654
2827	Journal of the Royal Statistical Society Series C-Applied Statistics	1.362

analysis is at the discipline level, which gives less insights into the variation across journals that we are interested in.

The question this paper will answer is: why do statistics journals have low IFs? One reason could be that they are cited later than other journals, resulting in a small numerator in the aforementioned definition of the IF. In order to test this, we employ the well-known Bass model (BASS, 1969). This allows us to test the differences between the diffusion of the statistics journals versus journals in other disciplines. For comparative purposes, we also collect citation data from various other disciplines, such as physics and biology, as well as some multidisciplinary journals.

The remainder of this paper is organized as follows. We next describe the data used in this study, as well as the approach we use to answer the above question. Next, we present our research findings. The paper ends with a discussion and conclusion.

## 2 Data

To investigate the differences in IFs between statistics journals and journals in other disciplines, we collect the following data from the 2007 ISI data, retrieved in October 2008. We include three statistics journals: *Journal of the Royal Statistical Society Series B–Statistical Methodology*, *Journal of the American Statistical Association* and *Annals of Statistics*. Following PHELAN (1999), who states that citation analysis is likely to be most reliable when the underlying data are at the highly cited end of the distribution, we consider the top 20 papers in terms of the number of citations for each of these journals. Using the top 20 indeed has the advantage of having enough observations to estimate our model described later on. Next, we also include the top 25 of the most cited statistics papers, by RYAN and WOODALL (2005). This top 25 contains statistical papers from various journals in different fields, ranging from the statistics journals mentioned above to journals like *Biometrics*, *Lancet*, *Evolution* and *British Journal of Cancer*.

For several other disciplines, we also collect 20 papers. The average number of citations differs strongly between the top 20 of the statistics papers and the top 20 of the major journals in the ‘other disciplines’ category, such as *Nature*, *Science*, *Physical Review Letters* and *Environmental Modelling & Software*. For the statistical papers ranked 11–20, the number of citations are around 1000, whereas for the three aforementioned journals these ranks have citations around 4000.

We want to make sure that differences we potentially find later on are not caused by this large discrepancy between the absolute number of citations. Therefore, for these high-impact journals, we also collect data for papers that have more or less the same number of total citations as the top 20 of statistics papers, i.e. around 1000. This number is measured by the mode of the citation counts of the top 20 papers in the statistics journals. The mean is influenced strongly by outliers, e.g. the most cited paper in the journal, which reaches over 30,000 in the case of *Journal of*

Table 2. Journals included in the analysis. For most journals, we collect the top 20 in terms of their citations. For the heavily cited journals, we collect the top 10 and a lower group of 10 papers, where the number of citations is better comparable to most of the papers in the top tens of the statistics journals.

Journal	Journal IF	Number of papers collected	Ranks of papers in terms of no. citations	Average number of citations for collected papers
<i>Statistics</i>				
1–Journal of the Royal Statistical Society Series B–Statistical Methodology	2.210	20	1–20	2462
2–Journal of the American Statistical Association	2.086	20	1–20	3196
3–Annals of Statistics	1.944	20	1–20	701
4–Top 25 of the most cited statistics papers*	NA	23	1–25	7158
<i>Other disciplines</i>				
5–Journal of Biological Chemistry	5.581	20	1–20	1637
6–Nature	28.751	10+10	1–10; 491–500	7152; 1008
7–Science	26.372	10+10	1–10; 491–500	8597; 1057
8–Water Resources Research	2.154	20	1–20	611
9–Physical Review Letters	6.944	10+10	1–10; 91–100	4184; 875
10–Environmental Modelling & Software	2.099	10	1–10	92
Total		193		2839

\*Based on RYAN and WOODALL (2005). Two of the top 25 were not available in ISI.

*the American Statistical Association* (‘Nonparametric-Estimation From Incomplete Observations’ by KAPLAN and MEIER, 1958). We will report results separately for the actual top 10 and the other 10 that are included. Table 2 shows the included journals, their IFs, the number of papers collected and the average number of citations for the papers that were collected.

### 3 Modelling approach

To answer the question why statistics journals have lower impact factors, we analyse if diffusion rates vary systematically across disciplines. Our approach is to estimate a Bass model (BASS, 1969) for each time series of the number of citations of a particular paper. Denote the number of citations a paper gets in year  $t$  by  $y_t$ , and the cumulative number of citations in year  $t$  by  $N_t$ . The Bass model then reads

$$y_t = mp + (q - p)N_{t-1} - q/mN_{t-1}^2. \tag{1}$$

The parameter  $p$  is usually interpreted as the innovation parameter (internal influence) and  $q$  is interpreted as the imitation parameter (external influence). The parameter  $m$  denotes the potential total number of citations, i.e. the saturation level. We are in particular interested in the timing of the peak of the citation count, denoted by  $T^*$ . From  $p$  and  $q$ , this number can be calculated as  $T^* = \log(q/p)/(p + q)$ . We take a slightly different estimation approach (see also FRANSES, 2003; and FOK and FRANSES, 2007). We rewrite the Bass model such that it is formulated in terms of the peak time  $T^*$ . Denote the value for  $N_t$  at the peak time  $T^*$  by  $m^*$ . FRANSES (2003) shows that  $p$  and  $q$  can be rewritten as

$$q = -\frac{\log(1 - 2m^*/m)}{2T^*(1 - m^*/m)}, \quad p = -(2m^*/m - 1)q. \quad (2)$$

Combining equations (1) and (2), it follows that we need to estimate the parameters  $m$ ,  $m^*$  and  $T^*$  for the following nonlinear model:

$$y_t = \frac{m(2m^*/m - 1)\log(1 - 2m^*/m)}{2T^*(1 - m^*/m)} - \frac{2m^*/m \log(1 - 2m^*/m)}{2T^*(1 - m^*/m)} N_{t-1} + \frac{\log(1 - 2m^*/m)}{2mT^*(1 - m^*/m)} N_{t-1}^2. \quad (3)$$

We use EViews 6 to estimate these parameters for each of the papers in our data set. Besides reporting the average  $T^*$  values per journal, we also test whether these averages differ significantly across disciplines.

Besides the peak period  $T^*$ , we are also interested in the percentage of citations a paper gets in the first 2 years after publication. This corresponds to the time window Thomson ISI uses to compute the IFs. For any year  $t$ , this percentage can be denoted by  $f(t) = N_t/m$ : the cumulative number of citations in year  $t$  divided by the potential number of citations. This number will give more conclusive insights into why the impact factors vary so dramatically across journals. For a particular period  $t$ , this percentage is computed as follows (see FRANSES, 2003, for a derivation):

$$f(t) = \frac{N_t}{m} = \frac{1 - (p/q) \exp(-(p+q)(t - T^*))}{1 + \exp(-(p+q)(t - T^*))}. \quad (4)$$

As said, we are interested in  $f(2)$ . For completeness, we will also compute this number for  $t=3$ , to get an insight into the speed of diffusion in the first few years after publication.

## 4 Results

When estimating the parameters of the 193 Bass models, it appeared that for some papers, even after experimenting with different starting values, convergence could not be achieved, or estimation resulted in one or more insignificant coefficients. These papers are therefore removed from the subsequent analysis. A reason might be that for these papers, the diffusion curves do not fit the Bass model, because of a very steep decline in the number of citations after the peak. This is especially true for *Science*, where most papers in the top 10 had to be removed from the analysis. For *Environmental Modelling & Software*, the reason for removal is that the cite numbers are relatively low. In total, 133 papers remain.

Next, we present the results for the two analyses described above. First, we look at the time to peak. Next, we investigate what percentage of citations take place in the first 2 and 3 years.

Table 3. Values for  $T^*$ , averaged per journal across papers, and  $P$ -values for test if peak differs from 2 or 3 years.

Journal	$n$	Mean $T^*$	SD $T^*$	P-value one-sample $t$ -test for...	
				$T^* = 2$	$T^* = 3$
1–Journal of the Royal Statistical Society Series B	15	29.10	13.82	0.000	0.000
2–Journal of the American Statistical Association	18	22.17	10.63	0.000	0.000
3–Annals of Statistics	15	16.98	8.03	0.000	0.000
4–Top 25 of the most cited statistics papers	18	23.70	8.50	0.000	0.000
5–Journal of Biological Chemistry	17	5.16	1.73	0.000	0.000
6–Nature	13	7.00	4.32	0.001	0.006
7–Science	7	8.36	10.24	0.151	0.215
8–Water Resources Research	17	16.11	6.03	0.000	0.000
9–Physical Review Letters	11	11.57	4.14	0.000	0.000
10–Environmental Modelling & Software	2	5.13	0.52	0.074	0.109

#### 4.1 Time to peak ( $T^*$ )

As mentioned before, we are interested in several statistics. First of all, we look at  $T^*$ , the period in which the peak of the citations is reached according to the reparameterized Bass model (3). In Table 3, we show the estimated values for  $T^*$ , averaged per journal, as well as some other statistics.

From these results, it is evident that the journals with high impact have early peaks. We use one-sample  $t$ -tests to investigate whether the average peak values differ significantly from 2 and 3 years. These tests indicate that the statistics journals all have peaks significantly later than 3 years. The journals *Science* and *Environmental Modelling & Software* have peak times that are not significantly different from 2 years. The same pattern emerges when looking at the  $t$ -test for 3 years. *Science* even has three papers in the top 10 with a peak in the number of citations before  $t=2$ . When looking at pairwise  $t$ -tests, the statistics journals in the top part of Table 3 differ significantly from the *Journal of Biological Chemistry*, *Nature*, *Science* and *Physical Review Letters*. The  $T^*$ -values for the bottom three papers in the table (*Water Resources Research*, *Physical Review Letters* and *Environmental Modelling & Software*) differ significantly from only one statistics journal, namely the *Journal of the Royal Statistical Society B*.

The papers in the top 25 have a rather late peak (around 24 years). Even though this top 25 consists solely of well-cited papers, most of them are relatively old. The year of publication varies from 1949 to 1986, with an average of 1968. It appears that the number of citations these papers get has built up rather slowly over time, hence the high  $T^*$ -values. It is surprising to see that *Environmental Modelling & Software*, a journal with relatively few papers in the ISI database (1200 versus more than 100,000 for *Nature* and *Science*), has a very short time to peak. At 95% confidence, it is not statistically different from 2 years. A reason might be that the authors in this field keep a close eye on each other's work, and cite each other frequently. Note however that this number is based on a low number of observations.

In Figure 1, we graphically show the relationship between the IF of a journal and the average time to peak that we estimated for the papers in our data set.

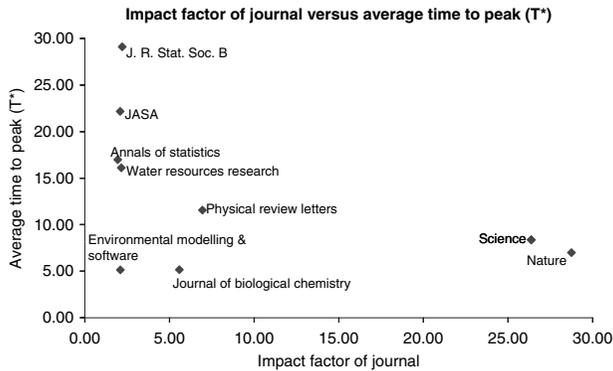


Fig. 1. Relationship between the impact of a journal and its average time to peak.

The correlation between these variables equals  $-0.47$ . This indicates that there is a moderate significant negative relationship between the IF and  $T^*$ : papers with higher IFs have a shorter time to peak. The correlation is more negative if *Environmental Modelling & Software* and *Journal of Biological Chemistry* are removed from Figure 1. In this situation, the correlation equals  $-0.77$ .

#### 4.2 Percentage of citations in first few years

With the peaks in the number of citations being several to many years beyond the ISI cut-off of 2 years, it is also interesting to investigate what the percentage of the potential total number ( $m$ ) of citations is at  $t=2$ . We compute this percentage with equation (4). We show both the information for the Top 10 in our data set, as well as the ‘lower ranks’, which in many cases simply consists of papers that are ranked on places 11 to 20, but for the well-cited journals this may be 491–500 (see Table 2 for details). For further insights, we also report the percentages for  $t=3$ .

The resulting percentages are displayed in Table 4. From these numbers, it is clear that *Journal of Biological Chemistry*, *Nature* and *Science* get a much higher percentage of their potential number of citations in the first 2 years. This is true for both the top 10 and the papers with lower ranks, indicating that this phenomenon is not caused by the absolute number of citations. The statistics journals get much lower percentages, although for the papers 11–20, the percentages appear a little higher for *Journal of the American Statistical Association*. This is also the case for *Physical Review Letters* and *Water Resources Research*. Just as we saw when looking at  $T^*$ -values, the top 25 has a very slow take-off, resulting in less than 1% after the first 2 years. Again, to a large extent, this has to do with the average age of the papers in this category.

Table 5 shows the results for  $t=3$ . The same pattern can be observed. We observe similarly high percentages for the same journals. It is interesting to see that *Annals of Statistics* has a faster take-off than *Journal of the American Statistical Association*, even though it has a slightly lower IF (1.944 versus 2.086, see Table 1). This

Table 4. Percentage of potential number of citations achieved in the first 2 years after publication, for the top 10 and remaining papers (see Table 2).

Journal	Top 10	Other 10
1–Journal of the Royal Statistical Society Series B-Statistical Methodology	1.15%	0.93%
2–Journal of the American Statistical Association	0.72%	1.41%
3–Annals of Statistics	1.93%	2.05%
4–Top 25 of the most cited statistics papers	0.96%	0.69%
5–Journal of Biological Chemistry	5.33%	7.03%
6–Nature	5.41%	2.82%
7–Science	7.49%	6.68%
8–Water Resources Research	1.66%	2.72%
9–Physical Review Letters	2.27%	3.22%
10–Environmental Modelling & Software	2.82%	
Total	2.64%	2.83%

Table 5. Percentage of potential number of citations achieved in the first 3 years after publication, for the top 10 and remaining papers (see Table 2).

Journal	Top 10	Remaining
1–Journal of the Royal Statistical Society Series B-Statistical Methodology	2.10%	1.44%
2–Journal of the American Statistical Association	1.16%	2.28%
3–Annals of Statistics	3.15%	3.39%
4–Top 25 of the most cited statistics papers	1.54%	1.12%
5–Journal of Biological Chemistry	9.57%	12.27%
6–Nature	9.55%	5.30%
7–Science	13.92%	11.59%
8–Water Resources Research	2.70%	4.37%
9–Physical Review Letters	3.67%	5.10%
10–Environmental Modelling & Software	5.09%	
Total	4.61%	4.80%

is most likely due to the fact that beyond the top 20 of papers collected, *Journal of the American Statistical Association* has papers with more immediate citations than does *Annals of Statistics*.

A one-way ANOVA on the percentages reported above indicates that all journals have significantly different averages. When checking which pairs differ significantly, we see a similar pattern as with the  $T^*$ -variable. The percentages for the four statistics journals differ significantly from the *Journal of Biological Chemistry*, *Nature* and *Science*. We also observe differences between these three journals and *Water Resources Research* and *Physical Review Letters*. The 2- and 3-year values tell the same story. As expected from these results, there is a significant relationship between the percentages and the IFs. For the top 10, the correlation is 0.82. Interestingly, beyond the top 10 the correlation drops to 0.48. A possible explanation for this is that the top papers determine the IF to a large extent.

## 5 Discussion

Based on the analysis of citation diffusion patterns, it has become clear that statistics journals enjoy slower diffusion than do journals in other disciplines. This has

Table 6. Percentage of citations out of potential reached at peak time.

Journal	$m/m^*$
1–Journal of the Royal Statistical Society Series B–Statistical Methodology	47%
2–Journal of the American Statistical Association	47%
3–Annals of Statistics	44%
4–Top 25 of the most cited statistics papers	47%
5–Journal of Biological Chemistry	38%
6–Nature	41%
7–Science	33%
8–Water Resources Research	45%
9–Physical Review Letters	41%
10–Environmental Modelling & Software	47%

consequences for the interpretation of the IFs, and may necessitate a rethinking of the method to compute the IFs. Based on their analysis of the aforementioned econometrics journals, FOK and FRANCES (2007) suggest that the time window used for calculating IFs should vary across journals, for instance have it depend on the average time-to-peak of the journal. In other words, this means that the current time window of 2 years is extended to a time window of  $T^*$  years, averaged across papers in the journal. This should diminish the differences we find in this study between the various disciplines, as each discipline has its own citation style. For instance, as FOK and FRANCES (2007) note, the medical journals cite each other immediately, because they concern health, an item of acute importance. In the study at hand, we also observed this phenomenon for the journal *Environmental Modelling & Software*, although because of the relatively low number of citations per paper, this finding was based on a small data set. Finally, the amount of self-citations, i.e. papers in a journal referring to papers in the same journal, might vary across disciplines (HEMINGSSON, 2002). This would also promote a change in the computation of the IFs.

It is interesting to analyze what the effect is of using the time-to-peak as the window for the IF for the disciplines in our data set. A direct way to investigate this is to look at the ratio  $m^*/m$ , the percentage of the potential number of citations that is reached at the peak time  $T^*$ . In Table 6, we report these numbers for the journals in our data set. The percentages appear to be higher for the statistics journals (average 46%) than for all other journals (average 40%), except for *Environmental Modelling & Software* (47%). These differences are significant (ANOVA,  $p < 0.001$ ). This means that using an IF where the time window with length  $T^*$  is used, would give statistics journals a better score than the other disciplines, because they score a higher percentage in this window than the other journals.

## 6 Conclusion

In this paper, we answered the question why statistics journals get lower IFs than journals in other disciplines. Even the top journal in the statistics discipline gets an

IF lower than 3. In other fields, much higher IFs can be observed. The average IF in the top 500 is as high as 8.

We analyzed the diffusion patterns of papers in several journals in various academic fields. We collected citation data for oft-cited papers in statistics journals, and for comparative purposes, we also collected citation data for journals in other disciplines. To obtain insights into the diffusion of the citation counts of the papers, the data were analyzed with the Bass model, leading to values for the time-to-peak that we can use to compare the speed of diffusion of the paper citations in the different disciplines. Estimation results showed that for statistics journals, it takes significantly more years to reach their peak. To further investigate diffusion, we also computed the percentages of the total number of citations a paper has after 2 or 3 years. Again, it appeared that statistics journals have slower citation diffusion than journals in other disciplines. Even the top statistic journal (*Journal of the Royal Statistical Society Series B—Statistical Methodology*) has a slower diffusion than the six non-statistical journals in our data set.

This is not to say that statistics journals have no impact on the academic world. It appears that the number of citations the papers in these journals get, takes off slower than in other academic fields. Indeed, as is the case with durables, not all take-offs are immediate (TELLIS *et al.*, 2003). Some papers might take time before citations begin to appear. It seems this is especially the case in the statistics discipline. For other disciplines, it appears that papers cite each other substantially quicker, such as in the medical field.

Finally, we investigated whether an alternative IF computation, as suggested in prior literature (FOK and FRANSES, 2007), would give the statistics journals a more favourable impact factor. When changing the time window from 2 years to the number of years it takes to the peak, the statistics journals appeared to achieve a higher percentage of their citations in this time window. This indicates that these journals would benefit from such a change in computation. Whether this change will be implemented is of course doubtful. In conclusion, we suggest that it is probably best not to look at bibliometric measures alone, but use them together with other research evaluation measures.

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