Does Format Make A Difference? Change in Print and Electronic Science Journal Impact Factors, 1992–2002

Jennifer K. Sweeney

Abstract

Studies of scholarly communication patterns indicate growing use of electronic journals, yet there is little knowledge of whether use of electronic format journals has had any influence on citation trends over time. This article reports findings from two studies comparing the trends in impact factors for science journals in two different formats: print-only and print-and-electronic ("hybrid"). In a pilot study, journal impact factors were compared for the years 1993 and 2001. The findings of the pilot study were replicated in a follow-up study for the years 1992 and 2002. Hybrid journals had significantly higher impact factors than print journals for all years. There was a difference between the trends in impact for print and hybrid journals during both time periods. Contrary to expectations, impact factors for hybrid journals tended to change only slightly, while impact factors for print journals increased significantly more than hybrid journals. The range of hybrid impact factors became more compressed, while the range of print impact factors expanded. The data appear to support Nieuwenhuysen's mathematical observation that journals with lower impact factors are likely to show more dramatic effects of fluctuation in impact than higher ranking journals. Further study of electronic journal citation and linking motivation and behavior is needed to understand the characteristics of these differences in citation measures.

Introduction

It has been over a decade since electronic journals began making their appearance on computer desktops. Along with the overall growth of digital information and the Internet, changes in the mechanisms and pace of electronic journal publication have transformed the practice of research and scholarly communication.[1] Intrinsic to the evaluation of rapidly changing scholarly journal collections lies the question of whether the use of electronic journals has influenced the ways in which researchers use journal literature overall.

There is ample evidence of the growth of the number of electronic publications,[2] as well as evidence of

Jennifer K. Sweeney is a student at the Department of Information Studies at the University of California, Los Angeles; e-mail: jksweene@ucla.edu.

how faculty and students are performing more "electronic activities"[3] and employing different techniques in their work related to using electronic information, including journals.[4] As electronic journals have become more available, they are clearly being used more often, and a corresponding decline in the use of print collections has been documented in many libraries. The literatures on journal use and bibliometrics do not discuss directly whether use has had any influence on impact, but an informal comparison of local use data in one university library showed a correspondence of high impact titles with high use, in both print and electronic formats.[5]

Given the continued proliferation of electronic journals and increased usage of electronic resources, it would not be unexpected for citation patterns to eventually shift in some way. Christine L. Borgman and Jonathan Furner write:

> What is new is that electronic scholarly communication is reaching critical mass, and we are witnessing qualitative and quantitative changes in the way that scholars communicate with each other… for constructing links between their work and the work of others.[6]

If journal use and citation behavior are related in some way, this raises several questions about bibliometric indicators for journals whose formats have shifted from print to electronic. Have impact factors for these journals changed during recent years? Have impact factors for print journals changed in the same manner as journals which have "gone electronic"? If there is a difference between print and electronic journal impact factors, what are the implications for the use of citation data in journal evaluation?

To answer these questions, a pilot study was formulated in 2001, during preparation for a review of a journal collection at the university library at the University of California, Davis. A larger follow up study was conducted in 2004. These are the studies reported in this paper. The research compared sets of science journals published in both print and print/electronic format (the latter is referred to here as *hybrid* format), for specified years between 1992 and 2002. The studies were based on the assumption that far fewer electronic journals were available during the early 1990s, and that by 2001 there had been sufficient growth in electronic titles for use of this format to begin to have an influence (if indeed one existed). Each study examined the same measure of citation behavior, the journal impact factor published in the Institute for Scientific Information (ISI) *Journal Citation Reports (JCR)*,[7] to ascertain whether any change in impact factor had occurred during that time period, and whether there was any difference in these trends between print and hybrid journal impact factors.

Review of the literature

Bibliometrics has a long history of use as a research method for studying scholarly communication. A review of the literature uncovered numerous longitudinal studies of scientific communities, authors, concepts, and other facets of publication, illustrating the ways in which science grows and changes.[8] A wide range of research questions have been addressed using bibliometric techniques at different levels of analysis, contributing to topics as diverse as journal ranking within disciplines, research communication patterns among scholars and communities, and research and development output of institutions and countries.[9] Most focus on one or more of three variables: producers (authors), products (artifacts) of communication, and concepts or ideas represented in communication.

Speaking about the use of bibliometrics in concept mapping, and long before electronic journals were commonplace, Eugene Garfield, Morton V. Malin, and Henry Small called for the study of citation metrics to evaluate the level and quality of scientific activity, admitting that "the problem of change is extremely complex," and that "we must be concerned with the evolution of systems over time and the sampling and measurement of systems at successive points in time."[10] New digital formats have added another dimension to this complexity.

Borgman notes that "citation analysis is most useful for achieving a macro perspective on scholarly communication processes through the use of voluminous datasets… citation analysis assumes that the authors or documents that are frequently cited have some importance, even if the reasons for the citations vary."[11] This assumption that citation indicators *mean something* is a key principle for all bibliometric analysis, but what that meaning is depends on the level and type of analysis chosen. Whether the reasons for citation in online or print formats are different, and if so, how they are different, is a valid research question, but it is outside the scope of this paper.

The journal citation indicators produced by the *JCR* fall into the artifact category, since they deal with scholarly published output. The impact factor is the most widely used indicator for journal evaluation in academic libraries, and is the measure used in this study. According to Virgil Diodato, the impact factor is "a measure of the importance or influence of a group of documents."[12] Essentially, it quantifies the popularity of a particular source document by counting the number of times it is cited in other documents within a specified time period. For detailed definitions of bibliometric terms and functions see Diodato and B.K. Sen.[13]

Issues and problems of citation analysis

The complexities of bibliometric analysis fall into several categories. One problem is comparing journals of different sizes. Since the number of articles published varies significantly from journal to journal, the ISI impact factor is calculated using a formula that theoretically allows comparison of impact across journals regardless of the number of articles, or productivity of the journal. Garfield has argued that correcting for this "productivity bias" is necessary to allow comparison of journals of varying size,[14] but there is evidence that despite the use of the ISI ratio there is still a productivity effect on impact. Ronald Rousseau and Guido Van Hooydonk[15] and Peter Vinkler[16] in particular have noted the linear relationship between journal productivity and ISI impact factor.

Michael H. MacRoberts and Barbara R. MacRoberts highlighted several additional categories of problems, focusing on inconsistencies between the scientific events documented in journal literature and the data elements in bibliographic citation used to describe those events, all of which contribute to inaccurate bibliometric description, or at least a high level of uncertainty.[17] These problems include citation bias via self-citation or incorrect attribution; lack of citation of informal influences such as personal communication; variation in types of materials cited; variation in citation rate depending on material type, language, time period, and specialty; and technical limitations of citation indexes such as authorship attribution and spelling, and literature coverage. While these differences among journals are important, researchers do not agree on the magnitude of their effects on bibliometric analysis, and it is possible that the magnitude of the effects depends on the level of analysis and the size and other characteristics of the data set, such as discipline and journal type.

Since neither the controversy over productivity bias nor the problems raised by MacRoberts and MacRoberts have been resolved, the validity of bibliometric analysis continues to rely on numerous assumptions and generalizations about citation context and other characteristics. This reliance may not be a hindrance to the study of impact factors for journal sets dispersed across disciplines, however.

As noted above, impact factors have been observed to vary by discipline and by document type, particularly for chemistry and mathematics, and for review journals.[18] This is not surprising given the differences in scholarly communication patterns across different fields and the specific purpose of review articles. Bibliometric research has supported the notion that scholars in different fields utilize different communication behaviors which can be reflected in citation patterns.[19] What is significant is that the linear relationship between journal productivity and impact factor noted by Vinkler, Rousseau and Van Hooydonk appears to persist across disciplines.[20]

Following this, other theorists have questioned to what extent contextual factors, such as field, journal type, misattribution, etc., need to be specified, given the complexity of the interactions in scientific communication practices across disciplines. Loet Leydesdorff relies on the understanding of social processes such as citation "as the selective operation of distributions upon underlying distributions," which thus allows the exploration of scientometrics (and by inclusion bibliometrics) to proceed mathematically.[21] Abraham Bookstein examined ambiguity and randomness in informetric distributions and demonstrated that random components can be incorporated in measurement with predictable consequences.[22] While the mathematics of Bookstein's model is beyond the scope of this paper, he describes the regularity of certain characteristics of informetric laws, particularly the Lotka distribution of publication events over time:

> I was able to examine … how the regularity varied in form as I introduced irregularities or simulated conceptual confusion… what I found was that the basic form of the regularity remained after the distortions were introduced, if it was present before.[23]

Analyzing trends in impact factors

Measuring bibliometric change over time is a complex task. A disparate set of influences affects bibliometric change: scientific discovery, the development of new technology, funding, and author idiosyncrasies affect the literature in definite yet indirect ways, resulting in a high level of uncertainty and randomness.[24]

Vinkler observed that the aging of information was a key factor in understanding how citedness changes over time, and introduced the relative publication growth (RPG) indicator for assessing this dynamic within and across journals.[25] Vinkler provided strong evidence that RPG can be multiplied with the ISI impact factor to predict citedness. His evidence demonstrated the tendency for impact factors to increase over time. This trend toward growth over time in publications as well as impact factor in various fields has been additionally supported in other bibliometric literature.[26] What is significant is that this finding appears to persist across disciplines.

Ambiguous and random influences on change in impact factors have been observed to be statistically regular and predictable. Bookstein considered the use of various statistical distributions to explain probabilities of bibliometric events that are determined by previous (known) values plus some random component.[27] He pointed out that statistical characteristics of the known functions tended to be very similar to the unknown or random functions. Thus, the influence of random effects could be predicted within some degree of accuracy. This is supported by Paul Nieuwenhuysen's prior work on randomness in bibliometrics.[28]

This apparent regularity of bibliometric response to random changes in the complex circumstances of scholarly communication is the grounding for the

Table 1. Subject breakdown of journals

		Pilot		Follow-up	
Subject	**LC #**	**Print**	**Hybrid**	**Print**	**Hybrid**
Mathematics	QA	1	26	24	32
Internal medicine	RC	0	0	17	32
Chemistry	QD	2	34	13	16
Natural history	QH	7	32	16	16
Microbiology	QR	0	7	10	15
Physiology	QP	0	27	7	14
Physics	QC	2	23	9	13
Agriculture (general)	S	1	7	12	13
Zoology	QL	9	15	22	11
Pharmacology	RM	0	0	5	11
Engineering (general)	TA	1	18	7	10
Plant culture	SB	3	8	8	8
Medicine (general)	R	2*	149*	17	7
Medicine (public aspects)	RA	0	0	2	5
Dermatology	RL	0	0	0	5
Chemical technology	TP	0	18	8	5
Geology	QE	6	21	6	4
Pathology	RB	0	0	6	4
Animal culture	SF	0	3	19	4
Mechanical engineering	TJ	0	6	0	4
Electrical engineering	TK	0	4	2	4
Science (general)	Q	1	5	8	3
Surgery	RD	0	0	2	3
Geography	GB	0	0	6	2
Oceanography	GC	0	0	0	2
Statistics	HA	0	0	3	2
Astronomy	QB	0	1	3	2
Botany	QK	2	7	15	2
Opthalmology	RE	0	0	1	2
Pediatrics	RJ	0	0	0	2
Aquaculture	SH	0	4	3	2
Environmental technology	TD	2	5	2	2
Mining and metallurgy	TN	1	2	2	2
Physical anthropology	GN	0	0	0	1
Otorhinolaryngology	RF	0	0	0	1

Table 1. Subject breakdown of journals

		Pilot		Follow-up	
Subject	**LC #**	**Print**	**Hybrid**	**Print**	**Hybrid**
Gynecology & obstetrics	RG	0	0	2	1
Dentistry	RK	0	0	5	1
Hydraulic engineering	TC	0	1	1	1
Manufactures	TS	0	1	4	1
Home economics	TX	1	3	3	1
Forestry	SD	1	0	1	0
Technology	T	0	2	0	0
Aeronautics	TL	1	0	2	0
Total titles		43	429	273	273

*LC call numbers for pilot study titles in the health sciences were not collected.

current study, which assumes a set of predictable and distinguishable behaviors associated with the use of materials regardless of variation in the factors noted by MacRoberts and others. This is required because of the multidisciplinary nature of the journals in the data set.

Method

This study asked two questions: first, whether impact factors of hybrid format journals were statistically different from print format journals, and second, whether there had been any significant difference in the evolution of these sets of impact factors for various years between 1992 and 2002.

Samples

Different sampling techniques were used for the pilot and follow up studies. The pilot study used a convenience sample made available during preparation for a review of the journal collection at the university library at the University of California, Davis. The follow up study used a random sample of the journals in the ISI *JCR* database. The change in sampling techniques was done to correct possible bias in the pilot study because of uneven numbers of print and hybrid journals in that study.

- Pilot study

For the pilot study, print journals were identified from a list of 600 print journals selected at random from the UC Davis library journal collection. These titles were searched in the *Jointly Administered Knowledge Environment (JAKE)* database to determine if the text of the items was available in electronic format anywhere as of 1999. The *JAKE* database is a free dataset containing a large body of information on electronic journals and other resources, such as coverage in full-text aggregated resources and indexing and abstracting coverage. It is maintained cooperatively by staff in several institutions.[29] Sixty-three titles in the initial set were determined to have no electronic version or counterpart available at that time.

Social science, humanities, and review journals were removed because these journals were observed to have a much wider range of bibliometric characteristics than the science journals. Non-English language titles were removed. Journals whose titles had changed were also removed. Content change within journals during the time period was not otherwise assessed. Of the remaining titles, complete impact factor data for 1993 and 2001 was located in the *JCR* for 43 titles in print format.

The hybrid titles were selected from a set of 630 titles in the UC Davis collections which, at the time of the research, were published by Elsevier *Science Direct*, Academic *Ideal*, and Blackwell *Synergy* in both print and electronic format. Of the titles in this set, social science and humanities titles as well as non-English language titles were removed, and complete impact factor data for 1993 and 2001 was located in the *JCR* for 429 titles available in both print and electronic format.

- Follow up study

For the follow up study, the online version of *Ulrich's Periodicals Directory* was used to search for titles in print-only format, using the same language, subject, and journal type criteria as the pilot study.[30] Complete impact factor data for 1992 and 2002 was located in the *JCR* for 273 titles.

Ulrich's Periodicals database was also used to locate titles in hybrid format by searching for journals published in both print and full text electronic format by Academic Press, Blackwell, Elsevier, Pergamon, W.B. Saunders, and Excerpta Medica. Complete data for 1992 and 2002 was found in the *JCR* for 395 titles. A sample of 273 of these were randomly selected in order to provide the same size sample as the print titles. The subject areas covered in the samples are summarized in Table 1. Circulation, publisher, and country of publication data were also collected from *Ulrich's* for the titles in the follow up study.

Descriptive statistics

- Impact factors for the journals were examined for basic statistical descriptors such as mean, median, minimum and maximum, range, and frequencies. A summary of this information is given in Table 2. The measure of the change in impact was calculated using a ratio; that is, 2001 values divided by 1993 values for the pilot study, and 2002 divided by 1992 for the follow up study. This was done to obtain a number reflecting the relationship of earlier to later values, regardless of impact factor value.

- Impact factors

The impact factors for both studies displayed frequencies skewed to the left, indicating that most of the impact factors were clustered in lower ranges. This is consonant with ISI data indicating that less than ten percent of the journal impact factors in the JCR are over 3.0.[31] Frequencies for the follow up study are shown in Figure 1 (Descriptive data for the pilot study displayed similar characteristics. For simplicity, the follow up study data only are used for illustration in this article).

- Change in impact from 1992 to 2002

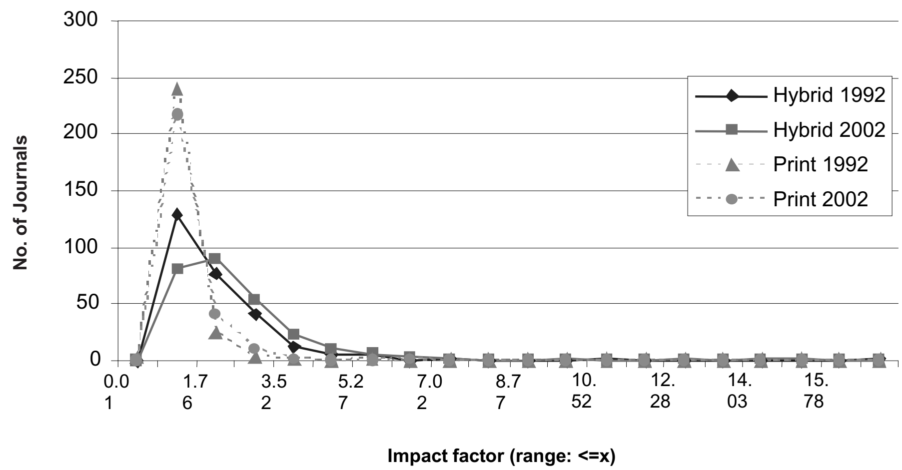
The scatterplot diagram in Figure 2 illustrates the change in impact factor from 1992 to 2002. Data along the x axis (bottom) represent 1992 impact values for each journal, and data along the y axis (left

Table 2. Descriptive statistics of impact factors

	Pilot					
	Print			Hybrid		
	1993	**2001**	**Change**	**1993**	**2001**	**Change**
Mean	0.671	0.921	2.136	1.548	1.993	1.514
Median	0.513	0.746	1.383	1.146	1.552	1.326
Standard Deviation	0.603379	0.670757	1.670423	1.825242	2.033331	0.789343
Skewness	1.221002	1.172519	1.636522	5.129956	3.941198	3.210437
Range	2.297	2.500	6.945	17.253	16.410	7.447
Minimum	0.011	0.083	0.600	0.046	0.065	0.314
Maximum	2.308	2.583	7.545	17.299	16.475	7.761
Sum	28.852	39.621	91.841	663.899	854.932	649.581
N=	43	43	43	429	429	429
	Follow up					
	Print			**Hybrid**		
	1992	2002	Change	1992	2002	Change
Mean	0.452	0.666	2.496	1.376	1.826	1.712
Median	0.327	0.545	1.626	0.935	1.369	1.401
Standard Deviation	0.499511	0.600172	2.904179	1.707825	1.741733	1.382488
Skewness	3.779164	3.791501	4.242998	5.585371	3.813588	5.753809
Range	4.766	6.063	23.821	16.602	14.198	13.853
Minimum	0.008	0.020	0.179	0.055	0.200	0.511
Maximum	4.774	6.083	24.000	16.657	14.398	14.364
Sum	123.500	181.895	681.395	375.6148	498.576	467.508
N=	273	273	273	273	273	273

side) 2002 values. Data points above the trend line indicate journals whose impacts factors increased, and data points below indicate journals whose impact factors have decreased. The majority of journals tended to increase or decrease within a limited area, with a few outliers exhibiting more dramatic change between 1992 and 2002. More journals increased (approximately 80 percent) than decreased (approximately 20 percent) for both print and hybrid journals.

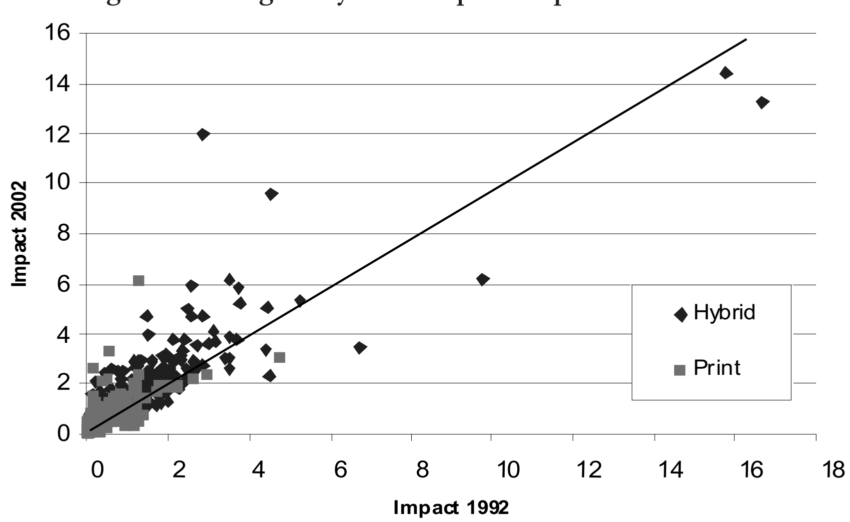
Figure 1. Print and hybrid impact factors



Frequencies for the change in impact for print and hybrid journals for the follow up study are shown in Figure 3. The pattern of change for print journals is clearly different from the hybrid journals, with more print journals demonstrating higher amounts of change, as shown on the right-hand side of the graph. On the left-hand side of the graph, more hybrid journals exhibit less change. Expressed another way, the print journals which increased, increased much more than the hybrid journals. This is shown in Table 3.

The breakdown of print and hybrid titles which increased and decreased by circulation and country of publication is provided in Tables 4 and 5.

Figure 2. Change in hybrid and print impact:s 1992 to 2002



Goodness-of-fit test

The next step was to find out whether the differences between print and hybrid change were statistically significant. The Chi-square distribution of the change in impact suggested that the data set might be appropriate for a goodness-of-fit test, a multinomial experiment. This statistical test is used to test the claim that a particular observed sample frequency distribution agrees with or fits some expected distribution.[32] In this case, the change in impact for print titles would be the expected distribution, and the change in the hybrid titles would be the observed distribution. Other requirements for this test were also met: the data were randomly sampled; the sample data consisted of frequency counts for each of the different categories; and the expected frequency was at least five in each category. In addition, the sum of the expected and observed frequencies must be equal.

The notation for the goodness-of-fit test includes the following:

O represents the observed frequency of an outcome (hybrid titles)

E represents the expected frequency of an outcome (print titles)

Table 3. Impact factor increase and decrease				
	Impact Increase		Impact Decrease	
	Print	Hybrid	Print	Hybrid
Mean	3.003	1.887	0.696	0.828
Median	1.949	1.543	0.737	0.869
Standard Deviation	3.104092405	1.4496051	0.1994248	0.12432634
Range	22.995	13.352	0.810	0.473
Minimum	1.005	1.012	0.179	0.511
Maximum	24.000	14.364	0.989	0.984
Sum	639.618	430.261	41.777	37.248
N=	213	228	60	45

k represents the number of different categories or outcomes

n represents the total number of trials

The sample sizes (*n*, above) in the follow up study were designed to be equal. However, to correct for the difference in sample sizes between print and hybrid sets in the pilot study, a bootstrapping technique was used to multiply the print frequencies by 10. Bootstrap methods are a group of mathematical procedures which provide an alternative way to make statistical inferences by repeated resampling.[33] Bootstrapping was introduced by Bradley Efron[34] and has been used in at least one other citation study.[35]

The hypotheses for this test are as follows:

H_o: That the observed (hybrid) frequency distribution conforms to the expected (print) frequency distribution

H_1: That the distributions are different

Using the following test statistic for goodness-of-fit-tests in multinomial experiments:

$X^2 = \Sigma \{ [(O - E)^2]/E\}$ and using the data on the change in impact for print and hybrid titles, it was found that for the sample titles in each study:

	Pilot	Follow up
N =	429	273
a =	.005	.005
p value =	21.955	21.955
$X^2 = \Sigma \{ [(O - E)^2]/E\}$=	129.565	72.785

Using a significance level of .005, the critical *p* value of 21.955 was obtained from a standard table of Chi-square distribution values.[36] The statistic for both the pilot and the follow up study fell well to the right of the critical value, within the critical region, indicating that the null hypothesis should be rejected. This result is illustrated in Figure 4.

Discussion

For the sake of brevity, the discussion will focus on the follow up study, since the statistical and descriptive characteristics of the pilot and follow up data sets are sufficiently similar. The descriptive statistics as well as the goodness-of-fit test provide several topics for discussion regarding areas of difference between the impact factors of print and hybrid journals.

- Hybrid journals: higher impact, compressed range

First, the impact factors of the hybrid journals were on the whole much higher than the print journals in 1992 as well as 2002. Hybrid journals exhibited consistently higher maximum, minimum, and consequently mean values. Hybrid titles also had a much larger range of impact. For example, the range of 1992 impact factors for the hybrid titles went from a minimum of .055 to a maximum of 16.657, while the range for print titles went from a minimum of .008 to a maximum of 4.774. The mean impact for print titles was half that of the hybrid titles for all years.

Caution is needed to interpret this finding. Although print journals appear to have much lower impact factors than hybrid journals, it is difficult to tell whether format per se has anything to do with this. It may simply be that publishers were more likely to select more successful journals with higher impact for electronic publication, rather than less influential titles. Journal productivity may also play a role, since higher productivity has been shown to be related to higher citation. Further research would be needed to establish this, since this study did not collect data on productivity.

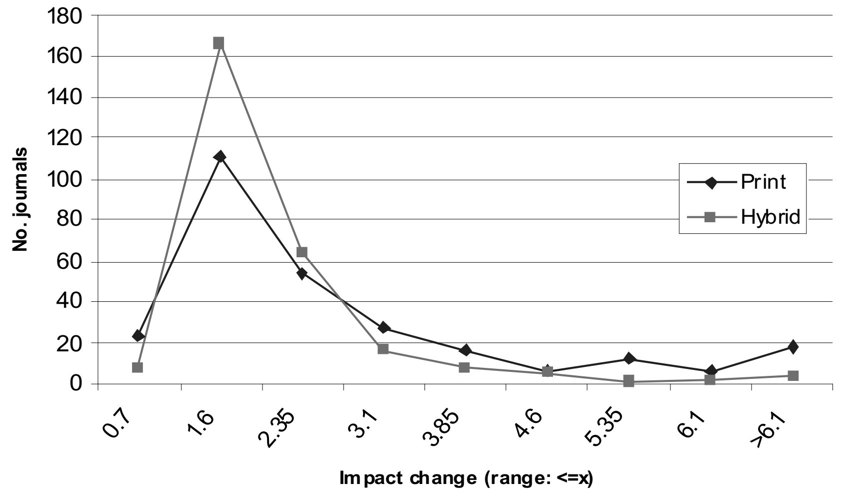
- Publishers, countries, and circulation

Print titles were more dispersed in publisher type and

Table 4. Country of publication

Print				Hybrid			
Impact increase	**No. of Titles**	**Impact decrease**	**No. of Titles**	**Impact increase**	**No. of Titles**	**Impact decrease**	**No. of Titles**
US	59	US	19				
UK	17	Germany	6	UK	43	UK	13
Canada	15	UK	4	US	24	Netherlands	2
Japan	14	Netherlands	4	Netherlands	12	Australia	1
India	12	Italy	4	Germany	8	Germany	1
Poland	11	India	4	Australia	5	US	1
New Zealand	10	Canada	3	France	1		
Czech Republic	9	Switerland	2	Ireland	1		
Italy	9	Israel	2				
France	6	Hungary	2				
Germany	5	Venezuela	1				
Australia	4	Sweden	1				
Denmark	4	South Africa	1				
Switzerland	4	Saudi Arabia	1				
Ireland	3	Russian Federation	1				
South Africa	3	Romania	1				
Spain	3	Puerto Rico	1				
Belgium	2	Japan	1				
China	2	France	1				
Croatia	2	Denmark	1				
Finland	2						
Greece	2						
Israel	2						
Mexico	2						
Netherlands	2						
Pakistan	2						
Saudi Arabia	2						
Argentina	1						
Bangladesh	1						
Costa Rica	1						
Hungary	1						
Korea, Republic of	1						
Slovakia	1						
Venezuela	1						
N=	215		60		94		18

Figure 3. Frequency of impact change for print and hybrid titles (2002/1992)



country, coming from 235 publishers in 33 countries. The types of publishers covered a broad mix of academic institutions, small and large commercial publishers, associations, and scholarly societies, with the majority coming from academic institutions, association, and scholarly societies. Circulation information was available for all the print titles but for only 111 of the 273 hybrid titles. According to these data, print titles appeared to have slightly higher reported circulation that the hybrid titles.

Characteristics of change in impact

• Impact increases over time

Vinkler and Jemec provided evidence that impact factors in general tend to increase over time because of the overall increase in the number of publications.[37] This was supported in general by the descriptive data in this study. Impact factors for sets of journals displayed consistent Chi-square shaped distributions, with data skewed to the left for all titles. This skew shifted slightly to the right in 2002 for both sets, showing the expected increase over time (see Figure 1).

• Hybrid: less change

Distribution of the change ratios for both print and hybrid titles also displayed a significant left skew (see Figure 3). Here the shape of the frequency distribution is different for print and hybrid change in impact factor, showing a compression of hybrid values and expansion of print values. Specifically, the mean change for hybrid journals was much lower than the print mean change, indicating that the impact factors for hybrid journals changed much less in the period from 1992 to 2002.

• Hybrid: range compression

One statistic in this area stands out: the range of impact factor values for hybrid journals decreased by almost 14 percent during the period from 1992 to 2002, while the range of print journal impact factors increased by 24 percent. The data in this study do not offer any direct explanation for this. At first glance, this result seems contrary to expectations. If we accept the notion that electronic materials are being used more frequently than print materials, it might be surmised that impact would increase commensurately. Although impact did increase for 80 percent of all titles, the decrease in range for hybrid titles shows that the higher impact factors for hybrid journals in 2002 in general were not quite as high as they were in 1992, and the lower impact factors were not quite as low. Correspondingly, the high impact factors for print in 2002 were higher than 1992, and the lower impact factors in 2002 were lower than 1992.

Table 5. Circulation

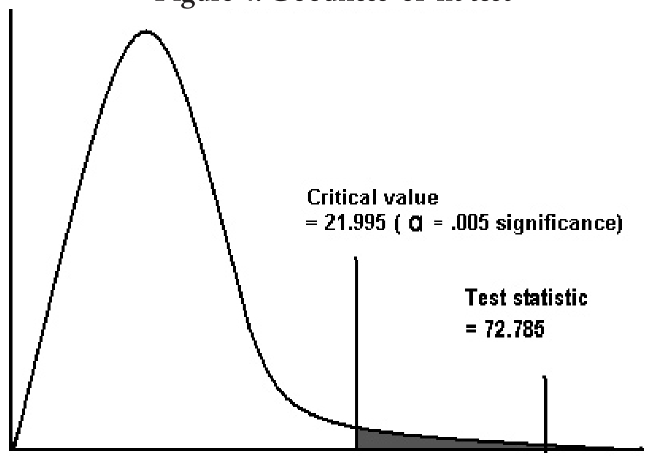
	Impact Increase		Impact Decrease	
	Print	Hybrid	Print	Hybrid
Mean	3,679	2,588	4,816	1,971
Standard Deviation	9628.5881	3533.844	14810.32662	1716.568
Median	1,200	1,500	1,123	1,558
Range	92,188	25,330	100,205	6,620
Minimum	200	168	244	380
Maximum	92,388	25,498	100,449	7,000
Sum	791,041	240,687	288,973	35,470
N=	215	93	60	18

Nieuwenhuysen offers a mathematical explanation for this compression of hybrid values and dispersal of print values. Relative fluctuation in citation measures results in more dramatic consequences for lower ranking journals.[38] Since print journals tend to have much lower impact than hybrid journals, relative shifts in amount of citation appear to have greater effect on print journals.

- Goodness-of-fit test: reject the null hypothesis

The goodness-of-fit test results indicated that there is sufficient evidence to reject the null hypothesis—that is, the change in impact factors of print and hybrid journals are not the same. These differences in change between print and hybrid journals were not entirely unexpected. Given the recent theorizing on the predictable nature of change over time despite random effects, it was expected that the hybrid journals, because of their newly acquired electronic format, might exhibit some more radical change in impact. And although the change exhibited by print and hybrid journals was indeed statistically different, print journals in fact *changed more* than hybrid journals, as shown in the higher number of print journals with higher amounts of change, indicated on the right hand side of Figure 3. Most of the change in hybrid journals was centered around 1.712. The mean change in impact of the print journals was 2.496, 46 percent higher than the mean for hybrid titles.

Figure 4. Goodness-of-fit test



Impact factors of hybrid journals thus might appear to be more stable over time than impact factors of print journals, at least for the time period in this study. Nieuwenhuysen's observation that the relative fluctuation in citation measures from year to year is greater for journals receiving fewer citations is once again applicable here. In this light it could be expected that journals with lower impact factors will exhibit higher amount of change. Given that the impact factors of the print journals were generally so much lower than the hybrid journals, this would not be unexpected.

Limitations of this study

Of the many limitations inherent in citation study, several in particular should be pointed out here. First, it is not known when each of the hybrid journals became available electronically, and so no assumptions can be made about the availability or amount of electronic use between 1992 and 2002.

Second, it is possible that higher values for hybrid impact factors may be a function of external factors and have little or nothing to do with format change. Specifically, the decision to make a title available online may be influenced by the impact factor value—that is, a publisher may have preferred to invest in more successful titles, and thus the titles available now online represent those with higher impact. In addition, the set of hybrid titles is limited to a small group of large journal publishers. The results in this study would need to be replicated using a more representative sample in order for the results to be generalizable.

Third, in the pilot study, print titles were included based on their status in 1999. Since the data were collected for the years 1993 and 2001, it is unknown whether any of the print titles were made available electronically subsequent to 1999 and prior to data collection in 2002.

Fourth, the broad journal set and wide time periods used in this study also cannot address the type of change in publication patterns represented by the emergence and/or decline of specialties within broader subject areas, some of which have been shown to grow rapidly and exponentially in early phases, then leveling out and declining as the research area or topic matures or is merged with another.[39]

Conclusion

The data in this study suggest the possibility of a relationship between impact and format. It is important to recognize that the differences in impact trends may reflect other external factors at work, such as publishing trends which were not measured here. Higher impact factors for hybrid journals may indicate publisher preference for selecting higher impact journals for electronic publication in the first place. Little is known about the reasons why a publisher may choose to not publish in electronic format as well.

Greater change in print format impact factors supports prior mathematical observations that the relative fluctuation of impact for lower ranking titles is more dramatic than for higher-impact titles. Compression of impact factors for larger number of electronic journals demonstrates less dramatic bibliometric change in journals with higher impact factors. Correspondingly, expansion of impact factors for print journals reflects a more visible bibliometric change in journals with lower impact factors.

The results in these studies suggest that changing formats are related to changes in citation measures in some way. The reasons for why this is so remain unclear, however. Further study is needed on the characteristics of electronic journal citation and linking to help librarians understand the implications of citation trends for journal evaluation. Clearly, if bibliometric data display significant differences for journals in different formats, collection librarians should rethink assumptions about evaluation methods related to format to assess journal quality accurately. Librarians have generally recognized that impact alone is not a sufficiently robust indicator of quality, and the data in this study suggest that format has some relationship to change in impact, especially for print journals whose impact, productivity, and use may be lower than journals available electronically.

Notes

1. Ann Peterson Bishop and Susan Leigh Star, "Social informatics of digital library use and infrastructure," *Annual Review of Information Science and Technology* 31 (1996): 301–401. Christine L. Borgman, "Digital libraries and the continuum of scholarly communication," *Journal of Documentation* 56 (2000): 412–30. Christine L. Borgman and Jonathan Furner, "Scholarly communication and bibliometrics," *Annual Review of Information Science and Technology* 36 (2002): 3–72. Lisa M. Covi, "Material mastery: situating digital library use in university research practices," *Information Processing and Management* 35 (1999): 293–316. Philip M. Davis and Suzanne A. Cohen, "The effect of the web on undergraduate citation behavior, 1996–1999," *JASIST* 52 (2001): 309–14.
2. Stephen P. Harter and Hak Joon Kim, "Accessing electronic journals and other e-publications: An empirical study," *College & Research Libraries* 57 (1996): 440–56. Dru Mogge, "Seven years of tracking electronic journal publishing: The ARL directory of electronic journals, newsletters and academic discussion lists," *Library Hi Tech* 17 (1999): 17–25.
3. Leo F. Egghe, "New informetric aspects of the Internet: Some reflections–many problems," *Journal of Information Science* 26 (2000): 329–35.
4. Ann Peterson Bishop, "Document structure and digital libraries: How researchers mobilize information in journal articles," *Information Processing and Management* 35 (1999): 255–79. Covi, "Material mastery." F.W. Lancaster, "Attitudes in academia toward feasibility and desirability of networked scholarly publishing," *Library Trends* 43 (1995): 741–52.
5. Jennifer K. Sweeney, unpublished journal cost and use data, General Library, University of California, Davis (2000).
6. Borgman and Furner, "Scholarly communication and bibliometrics," 3.
7. *Journal Citation Reports—Science Edition* (Philadelphia: Institute for Scientific Information, various editions).
8. William J. Paisley, *The flow of behavioral science information: a review of the research literature* (Stanford: Stanford University, Institute for Communication Research, 1965). Henry G. Small, "Multiple citation patterns in scientific literature: The circle and hill models," *Information Storage and Retrieval* 10 (1974): 393–402. Howard D. White and Katherine W. McCain, "Bibliometrics," *Annual review of information science and technology* 24 (1989): 119–68.
9. Christine L. Borgman, ed., *Scholarly communication and bibliometrics* (Newbury Park: Sage Publications, 1990):15–16.
10. Eugene Garfield, Morton V. Malin, and Henry Small, "Citation data as science indicators," in *Toward a metric of science: the advent of science indicators* (New York: Wiley, 1978), 179–207.
11. Borgman, *Scholarly communication and bibliometrics*, 26.
12. Virgil Diodato, *Dictionary of Bibliometrics* (New York: Haworth, 1994).
13. Ibid. B.K. Sen, "Symbols and formulas for a few bibliometric concepts," *Journal of Documentation* 55 (1999): 325–34.
14. Eugene Garfield, "Fortnightly review: How can impact factors be improved?" *BMJ* 313 (1996): 411–13.

15. Ronald Rousseau and Guido Van Hooydonk, "Journal production and journal impact factors," *JASIS* 47 (1996): 775-80.

16. Peter Vinkler, "Dynamic changes in the chance for citedness," *Scientometrics* 54 (2002): 421–34.

17. Michael H. MacRoberts and Barbara R. MacRoberts, "Problems of citation analysis: A critical review," *JASIS* 40 (1989): 342–49.

18. B.C. Perlitz, "Opinion paper: On the objectives of citation analysis: problems of theory and method," *JASIS* 43 (1992): 448–51. Rousseau and van Hooydonk, "Journal production," 775–80.

19. MacRoberts and MacRoberts, "Problems of citation analysis"

20. G. van Hooydonk, "Standardizing relative impacts: estimating the quality of research from citation counts," *JASIS* 49 (1998): 932–41.

21. Loet Leydesdorff, "Theories of citation?" *Scientometrics* 43 (1998): 5–25.

22. Abraham Bookstein, "Informetric distributions. III. Ambiguity and randomness," *JASIS* 48 (1997): 2–10.

23. Bookstein, "Informetric distributions," 4.

24. Robert J.W. Tijssen and Anthony F.J. van Raan, "Mapping changes in science and technology: Bibliometric co-occurrence analysis of the R&D literature," *Evaluation Review* 18 (1994): 98–115.

25. Vinkler, "Dynamic changes in the chance for citedness."

26. Joan Sabate, Andrew Duk, and Clovia L. Lee, "Publication trends of vegetarian nutrition articles in biomedical literature, 1966–1995," *American Journal of Clinical Nursing* 70 (suppl., 1999): 601S–7S. Boldt, Haisch, and Malek, "Changes in the impact factor," 842–49. Haseeb Rashid, "Bibliometric analysis as a tool in journal evaluation," *Serials Librarian* 20 (1991): 55–64.

27. Abraham Bookstein, "Informetric distributions."

28. Paul Niewenhuysen, "Journal citation measures: Taking into account their fluctuations from year to year," *Journal of Information Science* 15 (1989): 175–78.

29. See http://jakeopenly.com [cited 20 January 2001].

30. *Ulrich's Periodicals Directory* (New Providence, N.J.: R.R. Bowker, 2004). Ulrichsweb.com [cited February 4, 2004]. Available from http://www.ulrichsweb.com.

31. Eugene Garfield, "Fortnightly review".

32. Mario F. Triola, *Elementary statistics,* eighth edition (Boston: Addison Wesley Longman, 2000).

33. W. Paul Vogt, *Dictionary of Statistics and Methodology: A Nontechnical Guide for the Social Sciences* (Thousand Oaks, Calif.: Sage, 1999).

34. Bradley Efron, *The jackknife, the bootstrap and other resampling plans* (Philadelphia, Penn.: Society for Industrial and Applied Mathematics, 1982).

35. Jack P. Kleijnen and Willem Van Groenendaal, "Measuring the quality of publications: new methodology and case study," *Information Processing and Management* 36, (2000): 551–70.

36. Triola, *Elementary Statistics*. 766.

37. Gregir BE Jemec, "Impact factors of dermatological journals for 1991–2000," *BMC Dermatology* 1, no. 7 (2001). Boldt, Haisch, and Maleck, "Changes in the impact factor," 842–49. Vinkler, "Publication velocity," 163–76. Vinkler, "Dynamic changes," 421–34.

38. Paul Niewenhuysen, "Journal citation measures".

39. Garfield, Malin and Small, "Citation data," 179–207.

Bibliography

Bishop, Ann Peterson, "Document structure and digital libraries: How researchers mobilize information in journal articles," *Information Processing and Management* 35, no. 3 (1999): 255–79.

Bishop, Ann Peterson, and Susan Leigh Star, "Social informatics of digital library use and infrastructure," *Annual Review of Information Science and Technology* 31 (1996): 301–401.

Boldt, J., G. Haisch, and W. H. Maleck, "Changes in the impact factor of anesthesia/critical care journals within the past 10 years," *Acta Anaesthesiologica Scandinavica* 44 (2000): 842–49.

Bookstein, Abraham, "Informetric distributions. III. Ambiguity and randomness," *JASIS* 48, no. 1 (1997): 2–10.

Borgman, Christine L., *Scholarly communication and bibliometrics* (Newbury Park: Sage, 1990). .

Borgman, Christine L., "Digital libraries and the continuum of scholarly communication," *Journal of Documentation* 56, no. 4 (2000): 412–30.

Borgman, Christine L., and Jonathan Furner, "Scholarly communication and bibliometrics," *Annual Review of Information Science and Technology* 36 (2002): 3–72.

Covi, Lisa M., "Material mastery: situating digital library use in university research practices," *Information Processing and Management* 35, no. 3 (1999): 293–316.

Davis, Philip M. and Suzanne A. Cohen, "The effect of the web on undergraduate citation behavior, 1996–1999," *JASIST* 52, no. 4 (2001): 309–14.

Diodato, Virgil, *Dictionary of Bibliometrics* (New York: Hawarth, 1994).

Efron, Bradley, *The jackknife, the bootstrap and other resampling plans* (Philadelphia, Penn: Society for Industrial and Applied Mathematics, 1982).

Egghe, L., "New informetric aspects of the Internet: some reflections—many problems," *Journal of Information Science* 26, no. 5 (2000): 329–35.

Garfield, Eugene, "Fortnightly review: How can impact factors be improved?," *BMJ* 313, no. 7054 (1996): 411–13.

Garfield, Eugene, Morton V. Malin, and Henry Small, "Citation data as science indicators," in *Toward a metric of science: the advent of science indicators* (New York: Wiley, 1978): 179–207.

Harter, Stephen P., and Hak Joon Kim, "Accessing electronic journals and other e-publications: an empirical study," *College & Research Libraries* 57, no. 5 (1996): 440–56.

Jemec, Gregir BE, "Impact factors of dermatological journals for 1991–2000," *BMC Dermatology* 1, no. 7 (2001).

Journal Citation Reports—Science Edition (Philadelphia: Institute for Scientific Information, 1993). .

Kleijnen, P. C. Jack, and Willem Van Groenendaal, "Measuring the quality of publications: New methodology and case study," *Information Processing and Management* 36, (2000): 551–70.

Lancaster, F.W., "Attitudes in academia toward feasibility and desirability of networked scholarly publishing," *Library Trends* 43, (1995): 741–52.

Leyesdorff, Loet, "Theories of citation?," *Scientometrics* 43, no. 1 (1998): 5–25.

MacRoberts, Michael H. and Barbara R. MacRoberts, "Problems of citation analysis: A critical review," *JASIS* 40, no. 5 (1989): 342–49.

Mogge, Dru, "Seven years of tracking electronic journal publishing: The ARL directory of electronic journals, newsletters and academic discussion lists," *Library Hi Tech* 17, no. 1 (1999): 17–25.

Niewenhuysen, Paul, "Journal citation measures: Taking into account their fluctuations from year to year," *Journal of Information Science* 15, (1989): 175–78.

Paisley, William J., *The flow of behavioral science information: A review of the research literature* (Stanford: Stanford University, Institute for Communication Research, 1965). .

Perlitz, B.C., "Opinion paper: on the objectives of citation analysis: Problems of theory and method," *JASIS* 43, no. 6 (1992): 448–51.

Rashid, Haseeb, "Bibliometric analysis as a tool in journal evaluation," *Serials Librarian* 20, no. 2/3 (1991): 55–64.

Rousseau, Ronald and Guido Van Hooydonk, "Journal production and journal impact factors," *JASIS* 47, no. 19 (1996): 775–80.

Sabate, Joan, Andrew Duk, and Clovia L. Lee, "Publication trends of vegetarian nutrition articles in biomedical literature, 1966–1995," *American Journal of Clinical Nursing* 70 (suppl.), (1999): 601S–7S.

Sen, B.K., "Symbols and formulas for a few bibliometric concepts," *Journal of Documentation* 55, no. 3 (1999): 325–34.

Small, Henry G., "Multiple citation patterns in scientific literature: The circle and hill models," *Information Storage and Retrieval* 10, (1974): 393–402.

Sweeney, Jennifer K., "Journal cost and use data," *Unpublished data, General Library, University of California, Davis* (2000).

Tijssen, Robert J.W., and Anthony F.J. van Raan, "Mapping changes in science and technology: Bibliometric co-occurrence analysis of the R&D literature," *Evaluation Review* 18, no. 1 (1994): 98–115.

Triola, Mario F., *Elementary Statistics,* eighth edition (Boston: Addison Wesley Longman, 2000).

Ulrich's Periodicals Directory: Ulrichsweb.com (New Providence, N.J.: R.R. Bowker, 2004).

Van Hooydonk, G, "Standardizing relative impacts: Estimating the quality of research from citation counts," *JASIS* 49, no. 10 (1998): 932–41.

Vinkler, Peter, "Dynamic changes in the chance for citedness," *Scientometrics* 54, no. 3 (2002): 421–34.

Vogt, W. Paul, *Dictionary of statistics and methodology: A nontechnical guide for the social sciences* (Thousand Oaks, Calif.: Sage, 1999).

White, Howard D., and K. W. McCain, "Bibliometrics," *Annual review of information science and technology* 24, (1989): 119–68.