

# Do Open-Access Articles Have a Greater Research Impact?

Kristin Antelman

Although many authors believe that their work has a greater research impact if it is freely available, studies to demonstrate that impact are few. This study looks at articles in four disciplines at varying stages of adoption of open access—philosophy, political science, electrical and electronic engineering and mathematics—to see whether they have a greater impact as measured by citations in the ISI Web of Science database when their authors make them freely available on the Internet. The finding is that, across all four disciplines, freely available articles do have a greater research impact. Shedding light on this category of open access reveals that scholars in diverse disciplines are adopting open-access practices and being rewarded for it.



There is currently an explosion of interest in the academic and publishing communities about the promise—and possible perils—of open-access scholarship and publishing. Although the term “open access” is somewhat fluid, included under its banner are the so-called “two roads to open access”: open-access journals and “e-print” (i.e., preprints or postprints) repositories, both of which make the full text of scholarly articles freely available to everyone on the open Internet.<sup>1</sup> Although debate swirls around questions of copyright, peer review, and publishing costs, individual authors are taking action in this arena by posting their articles to personal or institutional Web pages and to disciplinary repositories.

Since Steve Lawrence circulated his study of the impact of free online avail-

ability of computer science conference documents under the catchy title “Online or Invisible,” the notion that freely available papers have a greater research impact has taken hold. (Lawrence’s preprint itself was evidence of this phenomenon: the version published in the journal *Nature* [under a different title] was almost an afterthought; more than seven hundred documents in Google reference “Online or Invisible.”<sup>2</sup>) Despite the limited domain of the Lawrence study, making it difficult to make assumptions about other disciplines based on his findings, it is now common to see the assertion that research impact is increased by open access. For example, Eugene Garfield casually noted in a recent post to the American Scientist Open Access Forum listserv that “it has been demonstrated that on line access improves both readership and citation

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impact."<sup>3</sup> Although this statement may be intuitively believable, the evidence to document it is still being collected. In addition to the Lawrence study, small studies of the research impact of e-prints have been done for physics, chemistry, and a subdiscipline of computer science.<sup>4-6</sup> Preliminary results from a larger study, which will look at articles from seven thousand journals from the ISI Web of Science database, indicate a significant increased research impact for open-access articles in physics.<sup>7</sup> In related research, a study performed using the Citebase data found that the more often a paper is downloaded, the more likely it is to be cited (with the strongest correlation for high-citation papers and authors).<sup>8</sup>

In April 2004, ISI released a study titled "The Impact of Open Access Journals," in which it compared impact factor and the number of citations of open-access journals in the natural sciences with non-open-access journals. ISI found that "the OA journals have a broadly similar citation pattern to other journals, but may have a slight tendency to earlier citations."<sup>9</sup> However, it qualifies the findings by noting that many of the journals in the study only recently shifted to open access, that high-profile titles (such as *PLoS Biology*) were too new to be included, and that their relatively small sample included many regional titles that would not be expected to be high-impact journals. It also should be noted that this study was of journals, not articles; it is open to question whether these two groups of journals are sufficiently comparable with one another in measures other than their access model to produce a meaningful gauge of the impact of open access. Given that we are at an early stage in the evolution of open-access journals, comparing the research impact of articles taken from the same issues of the same journals is a more solid methodology for measuring the impact of open access.

A common author perspective is reflected in a reported conversation with an electrophysiologist in the journal *Science*: "Free online papers are likely to reach more readers, he figures, and therefore attract more citations."<sup>10</sup> Backing this up is a survey of authors (primarily in the life and medical sciences) sponsored by the Joint Information Systems Committee (JISC), which found that the two principal reasons for publishing in an open-access journal was belief in "the principle of free access for all readers," followed by "I perceive OA journals to have faster publication times." The next two most important reasons were related to perception of research impact: "I perceive the readership to be larger" and "I think my article will be more frequently cited."<sup>11</sup> One quantifiable measure of authors' belief that free access is valuable to them is their adoption of an open-access option initiated by the Entomological Society of America and now offered by a number of publishers. After offering open access to individual articles for a (low) fee, they found that by the second year more than half of the authors elected to purchase it.<sup>12</sup>

There also is more indirect evidence of a link between free online availability and impact. Studies have shown that authors, as consumers of research information, rely heavily on browsing online journals and articles.<sup>13</sup> Brody and colleagues have used data from the CiteSeer repository to demonstrate that the "peak of citations occurs higher and sooner for papers deposited in each succeeding year."<sup>14</sup> Moreover, research has been done on the tangential question of whether online journals receive greater use than journals available only in print. That research, undertaken at a point when only a portion of journals were available in so-called "combination" online and print editions, did not make the distinction between ac-

cess to a licensed online version versus a freely available online version.<sup>15</sup>

University libraries contemplating providing support for open-access initiatives, such as institutional repositories or open-access journals, face several key challenges. Librarians must be able to draw on a sophisticated understanding of the scholarly communication practices of individual disciplines even as they are rapidly evolving, including scholars' use of prepublication research material not traditionally part of the domain of libraries in a print environment. If we choose to implement institutional repositories, we also must be able to persuade faculty, many of whom are for a variety of reasons quite reluctant, to contribute their prime research output. Data showing that freely available articles in their discipline are more likely to be cited is powerful evidence of the value of repositories as well as other open-access channels.

### The Research Question

This study's hypothesis is that scholarly articles from disciplines with varying rates of open-access adoption have a greater research impact if the articles are freely available online than if they are not. To determine whether a difference in impact exists, the mean citation rates, as recorded in the ISI Web of Science database, of freely available articles (1) were compared with those that are not (0) for a sample population of journal articles in four disciplines. The null hypothesis is that there is no difference between the mean citation rates:  $H_0: d_1 = d_0$ ;  $H_1: H_0$  is false.

These data provide a snapshot in time of open-access adoption in a few disparate disciplines. Within Christine L. Borgman's framework describing the intersection of scholarly communication and bibliometrics, this study examines the impact and potential of networked information

on artifacts of scholarly communication (published articles). Two of Borgman's four bibliometric research question types are addressed, namely, characterizing larger patterns of behavior in scholarly communities and evaluating measures of influence of scholarly contributions.<sup>16</sup>

This study does not attempt to address the variable of publisher policies regarding posting of pre- or postprints of articles from their journals, or the question of why authors choose to post or not to post e-prints.

### Methodology

The four disciplines—mathematics, electrical and electronic engineering, political science, and philosophy—were chosen with the expectation that they would represent different points on the continuum of open-access adoption. They also were selected as disciplines whose scholars have a tradition of active use of preprints. Ten leading journals in each discipline, as defined by ISI's Journal Citation Reports (JCR) for 2002 were selected (except philosophy, where there is no JCR).<sup>17</sup> High-impact journals were selected as indicators of leading researcher behavior while making no assumptions about journal quality. Open-access articles published in lower-impact journals may, in fact, have a greater relative research impact because they are not so widely available to authors through personal and institutional subscriptions.

ISI Web of Science citation data were used as a measure of research impact. Although citations cannot in themselves be said to measure research impact, nevertheless, citedness as measured by ISI is a measure that is commonly relied on as a surrogate for such impact.<sup>18,19</sup> Use of this inexact proxy for research impact is less of a concern in this study because citedness in this literature is itself viewed by scholars as an objective, at least in the

sciences and social sciences, and an actual assessment of research impact is not of interest but, rather, the effect of open access on one traditional and frequently used measure of research impact.

Articles from 2001 and 2002 were selected as the population from which to draw the sample. Philosophy was the exception, where 1999 and 2000 were selected because of the lower level of citation of philosophy articles.

**Sample**

A systematic presample, which included a minimum of fifty open-access and fifty restricted articles, was taken for each of the disciplines to estimate the expected frequency and variance of open access in each population in order to calculate the necessary sample sizes. (See table 1.) Data collection for political science and electrical and electronic engineering began at the midpoint of the population (the first 2002 issue) and expanded equally into the second half of 2001 and first half of 2002 until the sample target for open-access articles was reached. For mathematics and philosophy, where the frequency of the restricted and open-access articles, respectively, was low, data were taken for the entire population. A potential bias introduced, namely, that some journals have more articles per issue than others, is not a concern because it is unlikely that

an author who publishes a given article in a higher-page-count title is either more or less likely to post that article online than an author who publishes in a lower-page-count title.

**Data Collection**

Article titles and the number of citations to each article, as recorded in the ISI Web of Science database, were collected from the sample population. Self-citations, citations from articles within the same journal issue, and citations from 2004 were excluded. After collecting these data, the article title was searched as a phrase in Google. If any freely available full-text version (including drafts, preprints, and postprints) was available, the article was considered to be open access. Google is a particularly powerful search engine as it now indexes not only the full text of PDF files, but also some PostScript files. Zipped files and dvi files (output from the TeX typesetting program commonly used in mathematics), on the other hand, were only discoverable through Google from Web page links. Some full-text articles in mathematics, therefore, may have been missed; however, the majority of open-access articles in mathematics are contained in repositories, which are well indexed. (See table 2.) Searching on the full title, which in most cases was a phrase unique to an article, resulted in any full-

text copy of that article appearing at the top of the result list ahead of references to it (because the title is typically encoded in the title tag). Parenthetical additions to the title made by some philosophy journals were re-

<b>Discipline</b>	<b>ss (Total)</b>	<b>ss (1)</b>	<b>ss (0)</b>	<b>% of Total Open Access</b>
Philosophy	602	101	501	17
Political science	299	87	212	29
Electrical and electronic engineering	506	188	318	37
Mathematics	610	426	184	69
* (1) = open; (0) = not open				

**TABLE 2**  
**Where Open Access Articles Are Found (n = 50)**

Discipline	Author's Site	Discipline Repository	Other Repository	Dept'l / Company Site	Conf. / Assoc. / Project Site	Working Paper Series	Another Person's Site	Course Archive
Philosophy	36	7	0	1	2	2	0	2
Political science	23	3	2	5	6	8	0	3
Electrical and electronic engineering	25	9	0	9	2	0	4	1
Mathematics	15	30	0	0	3	0	1	1

moved before searching, as were nontext or encoded characters.

Three phenomena indicate that the total number of articles coded as open access may be underestimated. The first is that a number of articles were “ephemeral,” meaning that there was evidence that they were available at one time but not when the sample was taken (e.g., the link was dead). Another set of ephemeral articles is reflected in the practice of authors who post a preprint but remove it when the article is published or replace it with a link to the restricted publisher’s copy. Whether they do that knowing that that copy is restricted is not always clear. (Of course, it also is possible that articles available at the time of data collection were posted only recently.) There also is the likelihood that some article titles changed significantly enough to not be discoverable between the preprint and the final publication. Finally, because

only Google was searched, it is very likely that articles not indexed in Google would be discoverable through other search engines.

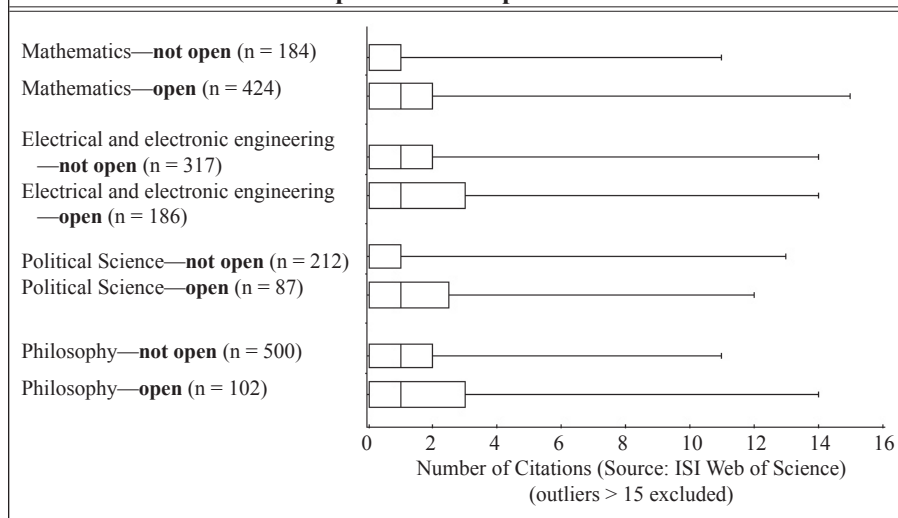
**Results and Discussion**

Because bibliographic distributions are highly skewed, the nonparametric equivalent of the t-test, the two-sided Wilcoxon signed rank test, was run for each discipline. (See table 3 for summary results.) The data show a significant difference in the mean citation rates of open-access articles and those that are not freely available online in all four disciplines. The relative increase in citations for open-access articles ranged from a low of 45 percent in philosophy to 51 percent in electrical and electronic engineering, 86 percent in political science, and 91 percent in mathematics. The disciplines selected did indeed represent a spectrum of adoption of open-access practices

**TABLE 3**  
**Comparison of Mean Citation Rates Between Freely Available Articles and Those That Are Not Freely Available**

Discipline	Mean (1)	Mean Standard Error (1)	Mean (0)	Mean Standard Error (0)	Difference in Means	Percent Difference in Means	Wilcoxon Two-tailed p Value	SD (1)	SD (0)
Philosophy	1.60	0.491	1.10	0.230	.500	45%	.0012	2.51	2.62
Political science	2.20	0.477	1.18	0.353	1.016	86%	<.0001	2.27	1.73
Electrical and electronic engineering	2.35	0.449	1.56	0.275	.798	51%	.0006	3.14	2.50
Mathematics	1.60	0.270	0.84	0.230	.762	91%	<.0001	2.84	1.60

**FIGURE 1**  
**Comparison of Citation Rates Across Disciplines**  
**for Open and Not Open Articles**



among scholars. Seventeen percent of articles in philosophy were open access; 29 percent in political science; 37 percent in electrical and electronic engineering; and 69 percent in mathematics (table 1). It is interesting to note that the discipline with the highest rate of adoption of open access (mathematics) is not the discipline with the greatest impact of open access on citation rates (political science). On the other hand, the discipline with the lowest open-access rate (philosophy) also exhibited the most tenuous link between citation and open access (the 95% confidence interval includes both means).

Although it has been shown that scientists prefer to access their research material online, and this study indicates that that may be the case for social scientists as well, it may well not yet be true for humanists.<sup>20</sup> It is likely that a critical mass of open articles is needed before authors will become accustomed to regularly looking for needed articles online but, when they do, the move away from print is irreversible. Research supporting this interpretation comprises studies done in

medical libraries (whose journals were the first to move online), which indicate that even journals only available in print—or back issues of online journals—started to see a dramatic decline in usage when a critical mass of journals went online.<sup>21</sup> As more research is available online, readers lower the threshold of effort they are willing to expend to retrieve documents that present *any* barriers to access. This indicates both a “push” away from print and a “pull” toward open access, which may strengthen the association between open access and research impact. As Lawrence hypothesized, it is likely that the greater citation rate for open-source articles indicates that authors are finding them more easily, reading them more often, and therefore citing them disproportionately in their own work. It is conceivable that the converse is true, that high impact articles are for some reason more likely to be posted online (maybe their authors get more requests for reprints and want to facilitate that process). However, that seems unlikely because the author behavior observed during the gathering of these

data indicates that the typical practice of each individual is to post either all or none of his or her articles.

Because comparing means of highly skewed distributions can be misleading, the citation distributions of each population were examined to see if there was a difference. The box plots in figure 1 show that across all disciplines the distribution of number of citations indicates that articles in the open-access sample have higher citation counts. These distributions also suggest that the greatest impact of open access is with the most-cited articles, as found by Steve Hitchcock et al. and Elana Broch had found.<sup>22</sup> This also is reflected in the higher standard deviations for the open sample for three of the four disciplines studied (philosophy being the exception).

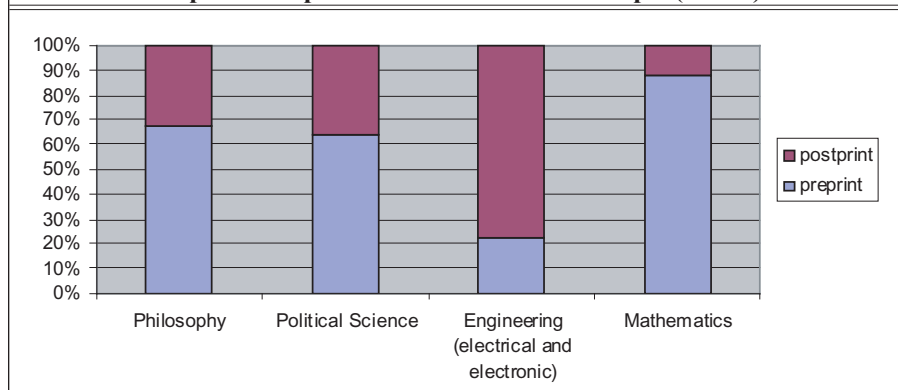
#### *Author and Reader Behaviors*

To better understand the individual choice that posting a research article online represents, subsamples of fifty open-access articles were sampled randomly from each discipline. For each article, its location was noted (table 2).<sup>23</sup> Links to articles most often were found on author home pages (50% overall) or in disciplinary repositories (25%), with clear differences across disciplines. Also noted was whether

the article was a preprint or a postprint, which also varies by discipline. (See figure 2.) Perhaps the fact that it is more typical to post a postprint in electrical and electronic engineering reflects a somewhat weaker preprint culture in that discipline. What is not reflected in these numbers is that some authors will post a preprint from a given journal and others will post a postprint. Thus, author choice is clearly a factor in the decision to post a pre- or postprint (as well as any restrictions a journal may place on posting pre- or postprints).

One conclusion that could be drawn from the increased citation rates of articles whose authors made them available as preprints is that preprints are being used as "near substitutes" for the less accessible published versions for many readers (although those readers still cite the published version).<sup>24</sup> In the increasing use and distribution of the preprint, there is a blurring of the boundary between "research documentation" and "scholarly literature," to use terms from an IFLA statement on open access.<sup>25</sup> A likely driver of the observed author behavior is that the more accessible online preprint, for disciplines that practice the exchange of preprints, is an innovation that facilitates long-established peer communication behavior.

**FIGURE 2**  
**Preprint/Postprint Distribution in Subsample (n = 50)**



One may speculate that when articles are only a mouse click away, "bad" author behaviors that have been described in the citation analysis literature will be less common. One example is citation bias, where authors reference only journals they can access.<sup>26</sup> Another author behavior that may become less prevalent thanks to open access is hollow citing, where the author does not read the article he or she cites, evidenced by the carrying forward of prior citation errors.<sup>27</sup>

### ***Publisher Behaviors***

Some interesting publisher practices also were uncovered during the course of this study. Publishers such as Blackwell, IEEE, ACM, and Kluwer are exposing article-level metadata, sometimes through formal agreements with Google, linking back to a restricted or pay-per-view copy.<sup>28</sup> The result is that the Google searcher will see as many as five or six different links to the restricted copy of the article. Google searching currently works in favor of the seeker of an open-access copy, however. If an open copy of the article is available, and the article itself has been indexed by Google, that copy will appear ahead of the restricted copies in the search results display. Where the open-access article itself is not indexed but is available through a link, the page with the link will follow the links to the restricted copies.

Publisher use of the Digital Object Identifier (DOI) to expose article-level metadata deserves singling out as a metadata exposure technique. Many publishers note the DOI on the electronic copy of the article and promote its use as a unique identifier for an article, one that some authors use on their own Web pages.<sup>29</sup> Publishers are currently leveraging the DOI through partnerships, such as the one between CrossRef and Google in which CrossRef will provide Google with publisher metadata, including DOIs.<sup>30</sup>

But because publishers register DOIs with the International DOI Foundation (IDF), which also provides resolution services, DOI links will always resolve to the publisher's copy of the article.<sup>31</sup> This practice points to the need for the DOI to be directly actionable on the Web, perhaps through the info URI, so that authors, libraries, or others could provide services that resolve DOI-based links to open-access (or locally licensed) copies of the articles.<sup>32</sup>

### **Conclusions**

This study indicates that, across a variety of disciplines, open-access articles have a greater research impact than articles that are not freely available. Although this finding is only a part of the complex picture of ongoing changes in scholarly communication in a networked information environment, it can help to inform librarians' strategies in working on initiatives such as building institutional repositories, pursuing open-access publishing alternatives, or working with faculty on negotiating rights with publishers. Understanding disciplinary differences in authors' posting of e-prints has implications for existing library services as well. Some approaches to changing the existing scholarly communication model, such as disciplinary or institutional repositories and open-access journals, are longer term and top-down. Author self-posting, as seen in the ad hoc manner in which it is occurring, is a present-day grassroots response to clearly perceived benefits in sharing scholarly output. Libraries as institutions must respond in both the long and short terms by participating in major new initiatives and at the same time better encompassing the new open-access literature in their collections. For instance, the contents of many repositories can be accessed using the Open Access Initiative Metadata Harvesting Protocol. In many



cases, simply passing a title through to Google would be a valuable addition to a reference linking service.

It is well known that despite the fact that such journal-level impact factors are routinely used to evaluate authors of individual articles, "journal impact factors correlate poorly with actual citations of individual articles."<sup>33</sup> The high standard deviations of these samples bear this out and point to the value of new citation measures, such as CiteSeer or ParaCite, which assess the impact of individual articles.<sup>34</sup> Open-access articles make these new, more meaningful measures of research impact possible. Evidence of the rapid evolution of bibliometrics toward "webometrics, "cybermetrics,"

and "influmetrics," as Blaise Cronin has characterized them, is the partnership between ISI and CiteSeer to create a new citation measurement tool.<sup>35,36</sup>

Studies such as this one can help to shed light on the "dark matter" of open access. Outside a few disciplines, the majority of freely available articles will not be found in a repository or in an open-access journal but, rather, on personal home pages. Those articles are not amenable to collecting hit-count measures of use, yet they are clearly used. Shedding light on this category of open access reveals that scholars in diverse disciplines are adopting open-access practices at a surprisingly high rate and are being rewarded for it, as reflected in a traditional measure of research impact.

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### Notes

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8. *Ibid.* Correlation Generator available online at <http://citebase.eprints.org/analysis/correlation.php>. [Cited 13 March 2004].

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10. David Malakoff, "Opening the Books on Open Access," *Science* 302 (Oct. 24, 2003): 552.

11. "JISC and Publishers Work Together to Open Up Access to Journals," press release. Available online from [http://www.jisc.ac.uk/index.cfm?name=news\\_openaccess\\_0304](http://www.jisc.ac.uk/index.cfm?name=news_openaccess_0304). [Cited 18 March 2004].

12. Thomas J. Walker, "Two Societies Show How to Profit by Providing Free Access," *Learned Publishing* 15 (2002): 279–84. Publishers offering this option to authors and rates of adoption for 2003 include: Entomological Society of American for four journals (62%); Oxford University Press for *Nucleic Acids Research* annual issue, American Society of Limnology and *Oceanography for Limnology and Oceanography* (46%), American Physiological Society for *Physiological Genomics*, Company of Bi-

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14. Steve Hitchcock, Donna Bergmark, Tim Brody, et al., "Open Citation Linking," *D-Lib Magazine* 8 (Oct. 2002). Available online at <http://www.dlib.org/dlib/october02/hitchcock/10hitchcock.html>. [Cited 13 March 2004].

15. "Collection Management Strategies in a Digital Environment," final report to the Andrew W. Mellon Foundation, January 2004. Available online from <http://www.ucop.edu/cmi/finalreport/index.html>. [Cited 13 March 2004]; Eun-Ja Shin, "Do Impact Factors Change with a Change of Medium? A Comparison of Impact Factors When Publication Is by Paper and through Parallel Publishing," *Journal of Information Science* 29 (2003): 527–33; Andrew Odlyzko, "The Rapid Evolution of Scholarly Communication," *Learned Publishing* 15 (Jan. 2002): 7–19.

16. The others are evolution of scholarly communities and diffusion studies. Christine L. Borgman, "Bibliometrics and Scholarly Communication," *Communication Research* 16 (Oct. 1989): 589–90.

17. Philosophy journals were selected by using a combination of methods. *Ulrich's International Periodicals Directory*, *Magazines in Libraries*, online college or university library pathfinders, and individual scholars were consulted to develop a set of leading philosophy titles. Finally, to be included in the sample, titles had to be indexed by Philosopher's Index and have five or more citations to the journal in ISI Web of Science in the year 2000. The journals included in the sample follow. For philosophy, *American Philosophical Quarterly*, *The British Journal for the Philosophy of Science*, *British Journal of Aesthetics*, *Ethics*, *Journal of Philosophical Logic*, *Journal of Philosophy*, *Mind*, *Noûs*, *The Philosophical Quarterly*, and *Philosophical Review*; for political science, *American Journal of Political Science*, *American Political Science Review*, *Annual Review of Political Science*, *British Journal of Political Science*, *Comparative Political Studies*, *Comparative Politics*, *Journal of Conflict Resolution*, *Journal of Peace Research*, *Political Geography*, and *Public Opinion Quarterly*; for electrical and electronic engineering, *IEEE Communications Magazine*, *IEEE Electron Device Letters*, *IEEE Journal of Selected Topics in Quantum Electronics*, *IEEE Network*, *IEEE Signal Processing Magazine*, *IEEE Transactions on Image Processing*, *IEEE Transactions on Medical Imaging*, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *Journal of Microelectromechanical Systems*, and *Proceedings of the IEEE*; for mathematics, *Acta Mathematica*, *Annales Scientifiques de L'Ecole Normale Supérieure*, *Annals of Mathematics*, *Bulletin of the American Mathematical Society*, *Communications on Pure and Applied Mathematics*, *Foundations of Computational Mathematics*, *Inventiones Mathematicae*, *Journal of the American Mathematical Society*, *Random Structures & Algorithms*, and *Computational Geometry—Theory and Applications*.

18. Locke J. Morrisey, "Bibliometric and Bibliographic Analysis in an Era of Electronic Scholarly Communication," *Science and Technology Libraries* 22 (2002): 149–60.

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22. Steve Hitchcock, Tim Brody, Christopher Gutteridge, Les Carr and Stevan Harnad, "The Impact of OAI-based Search on Access to Research Journal Papers," *Serials* 16 (November 2003). Available online at <http://opcit.eprints.org/serials-short/serials11.html>. [Cited 21 July 2004]. Broch, "Cite Me, Cite My References?"

23. The location was coded as a department site if it was linked from a departmental page, even when it was stored in an individual's file space; it was coded as being on the author's site if the link was from an individual's curriculum vitae or located in a personal directory. If there was a repository copy, the article was coded repository even when a copy was also on the author's site.

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