Revisiting Methodology for Identifying Open Access Advantages

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Sumiko Asai

Professor, School of Political Science and Economics,

Meiji University

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Abstract

Although many empirical studies have investigated whether open access increases citations, researchers have not reached a consensus regarding the issue. This study revisited the methodology for identifying the effects of open access and revealed the causes for contradictory conclusions using four indices for journals that transitioned from subscription to open access. The four indices are two citation scores along with the number of citations and number of articles for eight journals independently launched by leading publishers. Correlation coefficients were used to compare the time trends in the values of the four indices. Although the aggregated data of the eight journals indicated that open access had a positive effect, the effect varied across journals. A few journals produced different results between the two citation scores as well as between citation scores and number of citations or articles. Furthermore, a publisher's choice of which journal to shift to open access influenced their performance after the shift. Therefore, results varied based on the choice of journals, indices, and types of data (aggregated vs. individual journals), leading to contradictory conclusions regarding open access advantages.

Keywords: shift to open access, citation numbers, article numbers, source-normalized impact per paper, Scimago journal rank, subscription journal

Introduction

Since the 2000s, open access journals have become increasingly popular in conjunction with the proliferation of the Internet and the rise in subscription journal prices. Moreover, open access initiatives, such as Plan S, mandate that authors publish funded research in open access journals, increasing their demand. With the development of open access, for-profit publishers, and research institutes, such as universities and academic societies, have

launched fully open access journals and shifted some of their subscription journals to open access. By switching from subscription to open access, publishers shift the revenue source from subscription fees to article processing charges (APCs) paid by authors and research funders. Although several open access journals published by research institutes do not charge APCs, for-profit publishers' revenues from open access journals are determined by the level of APC and the number of articles published. Therefore, the number of articles is a matter of concern for them, in addition to citation scores representing journal quality.

Many empirical studies have used various approaches to examine open access advantages since the 2000s. The first approach compares the number of citations (or citation scores) between randomly sampled subscription and open access articles or journals [1–9]. The second approach uses econometric methodology to formulate a citation equation using independent variables, including a variable indicating whether an article is open access [10–21]. Moreover, the third approach examines the changes in citation scores for individual journals that shifted from subscription to open access using time trend data [22–24].

Even though many empirical studies have examined the advantages of open access, researchers have not reached a consensus on this matter, according to Langham-Putrow et al. [25], who reviewed articles on open access advantages. There may be two reasons for these different conclusions. First, previous studies have investigated journals with various characteristics to analyze the impact of the shift from subscription to open access [26]. For example, some journals shifted from subscription to open access without changing publishers (e.g., *Conservation Letters*), whereas others launched independently by for-profit publishers changed publishers when shifting to open access (e.g., *Paladyn: Journal of Behavioral Robotics*). Research institute journals launched independently shifted to open access journals published by for-profit publishers on their behalf (e.g.,

Botanical Studies), whereas other research institute journals published by for-profit publishers on their behalf changed publishers when shifting to open access (e.g., *Earth, Planets and Space*). Thus, journals often change publishers when they shift from subscription to open access. In these cases, a shift from subscription to open access combined with a change in publisher may influence citation scores and other journal performance, such as the number of articles published. Additionally, languages, editorial policies, and acceptance rates may influence journal performance. When researchers investigate various types of journals to examine the advantages of open access, they must identify the influences of the other factors. However, separation of factors is difficult. Therefore, although the sample size is extremely small, this study examined eight English open access journals launched independently by leading publishers that shifted from subscription without changing publishers.

Second, conclusions regarding the advantages of open access may be influenced by the indices selected by the researchers. Although previous studies often used citation scores to examine the advantages, there are several indices that represent citation scores, such as impact factors, CiteScore, Source-Normalized Impact per Paper (SNIP), and the Scimago Journal Rank (SJR). Moreover, the number of citations is an index representing the degree of citation. Since the results may differ depending on the index chosen, this study employed four indices representing journal performance to compare the results obtained by these different indices. It is not possible to generalize the results of testing for open access advantages based on a small number of observations. However, this study aims to revisit the methodology for investigating open access advantages, contributing to the development of the bibliography field.

Related Literature

This section surveys previous studies on open access advantages. For studies using the

first approach described in Section 1, Lawrence [1] compared offline article citations with citations of freely available online articles in the field of computer science and reported that the mean of online article citations (7.03) was 2.5 times greater than that of offline article citations (2.74). Antelman [2] compared the number of citations between open access and non-open access articles in four disciplines: philosophy, political science, electronic engineering, as well as mathematics, finding that open access articles had more citations in these disciplines. In contrast, Björk and Solomon [3] investigated open access advantages for many journals and revealed that the impact factors for subscription journals were higher than those for open access journals. Using a large sample, Piwowar et al. [4] found that articles in fully open access journals had fewer citations than non-open access articles. Moreover, Perianes-Rodríguez and Olmeda-Gómez [5] investigated the number of articles and citations according to the journal type and found that the open access articles were not frequently cited compared with those in journals of other types. In contrast, Sotudeh et al. [6] revealed that open access journals published by Elsevier and Springer had an advantage in terms of citations, particularly in the natural sciences. Additionally, Hua et al. [7] compared the citations between open access and non-open access articles in oncology and concluded that open access articles had a higher citation rate than non-open access articles. Similarly, AlRyalat et al. [8] compared the median of the number of articles and citation scores in oncology journals between open and non-open access journals. AlRyalat et al. [8] revealed that whereas open access journals had higher citation scores, they published a smaller number of articles than non-open access journals. According to Pollock and Michael [9], the difference in impact factors between open access and non-open access journals decreased in 2017, as the impact factors for open access journals increased significantly. Recent studies on open access advantages employed large samples, but the conclusions differed across studies.

In a second approach, econometrics researchers have examined the effects of open

access by formulating a citation equation since the late 2000s. Through this approach, it is possible to separate the effects of open access from other factors, such as the characteristics of the articles and authors. By using a stepwise backward logistic regression model, Eysenbach [10] examined the effect of open access on citations in a hybrid journal and found that open access articles were more frequently cited in their early stages than non-open access articles. Moreover, Frandsen [11] used regression analysis to examine the effects of open access on citations in three fields (biology, mathematics, and pharmacology) and revealed that the effects differed across academic fields. Lansingh and Carter [12] investigated citations in an ophthalmic journal through a general linear model using variables representing the number of authors, funding, and the region in which the article was published. They concluded that open access did not have a statistically significant impact on citations, although the mean number of citations for open access articles was larger than that for articles in subscription journals. Davis [13] used regression analysis to investigate the effects of open access on citations for 11 hybrid journals and found that two of them had positive open access effects on the number of citations. Subsequently, Davis [14] analyzed the effects of open access on the number of downloads and citations in scientific hybrid journals and revealed that the number of downloads for open access articles was greater than that of non-open access articles, but the effect on citations was insignificant. Davis [13] concluded that although open access publishing reached more readers, these additional readers did not generate more citations. Furthermore, McCabe and Snyder [15] examined the effects of open access on citations in hybrid journals in the field of science and found that open access increased the number of citations by eight percent, but the effect was not substantial. Using the difference-in-difference method, Li et al. [16] examined CiteScores for journals across various disciplines and concluded that open access positively impacted citation scores. The open access advantages were also found by Breugelmans et al. [17], who examined the citation

scores for articles related to poverty-related diseases using a generalized linear model. Moreover, Patel et al. [18] examined the number of citations for articles in four cardiovascular journals using a multivariable Poisson regression model and revealed that the citation rate for open access articles was 1.5 times higher than that for non-open access articles after adjusting for article characteristics. In contrast, Mueller-Langer and Watt [19] investigated the effects of open access on citations in hybrid economic journals using the Poisson quasi-maximum likelihood regression and concluded that the effect was not significant. Using a regression model, Alkhawtani et al. [20] examined the number of citations for articles in a journal titled *European Radiology* and revealed that open access increased the number of citations and article downloads. Moreover, Clayson et al. [21] investigated articles in electrophysiology using a negative binominal model and concluded that open access articles increased the number of citations by 9% to 21% and Altmetric mentions by 39% as compared to non-open access articles.

For studies using the third approach, Cooney-McQuat et al. [22] reported that the impact factor of *Acta Veterinaria Scandinavica*, a journal published by an academic society, increased after a shift to open access. However, while shifting to open access, the academic society began publishing the journal in collaboration with BMC (formerly BioMed Central), a prestigious open access publisher. The increased impact factor may be attributed to the shift to open access and to the collaboration with the publisher. Bautista-Puig et al. [23] examined the citation scores and number of articles for over 100 journals that shifted from subscription to open access using the Directory of Open Access Journals and the Open Access Directory. They reported that the shift to open access led to an increase in citation scores, whereas there was no significant increase in the number of articles. However, although they found that various factors influenced citation scores, the influences were not separated. Using a similar methodology to Bautista-Puig et al. [23], Momeni et al. [24] investigated the effect of the shift from subscription to open

access and concluded that both the number of articles and citation scores increased following the shift.

Thus, conclusions regarding open access advantages differ across studies. If studies using econometric methodology properly formulate a citation equation, the influence of open access and other factors can be separated. However, most studies using the second approach examined open access and non-open access articles in a hybrid journal to exclude the influence of journal characteristics. Therefore, the types of journals investigated were limited. Moreover, most studies investigated open access advantages using a single index, which was applied to all three approaches.

Method

Target Journal

This study investigated open access journals that met the following criteria. First, the journals must have shifted from subscription to open access before 2017 to permit investigating journal performance before and after the shift. Second, these journals must have been indexed in Scopus to examine changes in citation scores. Third, they must have been published in English in order to exclude any influence of the publication language. Fourth, they must have been independently launched by a for-profit publisher or a university press. There are numerous open access journals affiliated with research institutes among journals published by leading publishers. Changes in the editorial policies of research institutes may influence journal characteristics, such as citation scores and the number of articles. Therefore, this study excluded journals published by or for research institutes to evaluate publishers' open access strategies. Information on whether each journal is published on behalf of a research institute or independently launched by a publisher was gathered from publishers' websites. The journal was considered independently launched when a research institute's website lacked information about it.

Ultimately, this study compiled eight journals that met these requirements.

Elsevier publishes four of the eight journals, and Oxford University Press, Springer Nature, Taylor & Francis, and Wiley each publish one. Table 1 outlines the eight journals by their title, publisher, start year of open access, sample period, and the applicable APC in 2021, measured in US dollars (USD). *Nuclear Physics B* and *Physics Letters B*, published by Elsevier, do not charge any APCs because they are covered by the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP^3), a global network of funding agencies [27]. *Nature Communications* launched as an electronic hybrid journal in 2010 declared a shift to fully open access in 2014 and actually became a fully open access journal in 2016.

(Table 1 near here)

Indices

Journals that publish a small number of frequently cited articles are likely to have a high citation score, but their total number of citations will not be very high. In contrast, when a journal publishes many articles that are not very frequently cited, the journal may have many citations despite its low citation score. Although journal quality is generally measured by citation scores in the Web of Science and Scopus, the number of citations is also an important index representing the journal's degree of academic influence. The number of articles or pages per issue in a printed subscription journal is restricted by the journal's production budget. In contrast, open access journals that are distributed electronically can publish numerous articles without capacity restrictions. Moreover, as more articles in an open access journal earn more APC revenue, publishers of these journals have an incentive to publish many articles.

Although CiteScore in Scopus is frequently employed for citation analysis, Scopus provides longer-term trend data for SJR and SNIP than CiteScore. SJR weights citations based on the prestige of the journal [28], whereas SNIP is normalized to correct the

differences in citation practices among academic fields [29]. This study used four indices in the analysis: *SJR*, *SNIP*, the number of citations (*Citation*), and the number of articles (*Article*). The two former indices represent journals' qualitative factors, whereas the two latter indices represent quantitative factors. These indices were sourced from Scopus. The four indices and publication year (*Year*) as variables are presented in italics.

Results

As citation data for *Nature Communications*, which was launched in 2010, are available since 2011, this study calculated the means of the four indices for the eight journals during the period of 2011–2020. The mean *SJR* for the eight journals increased from 2.431 in 2011 to 2.638 in 2020, whereas the means *SNIP* increased from 1.498 in 2011 to 1.875 in 2020. Thus, both citation scores increased over the 10 years. Moreover, the mean *Citation* significantly increased from 32,329 in 2011 to 97,519 in 2020, whereas the mean *Article* increased from 396 in 2011 to 1,179 in 2020. The aggregate number of citations and articles consistently increased and tripled during this period. Based on the aggregated data, it appears that the shift to open access had a positive effect on academic influence. However, the effects differed across journals.

Table 2 presents the means of the four indices for individual journals at three-year intervals, in principle, before and after the shift to open access. The correlation coefficients between these indices and the *Year* indicate the time trend. *SJR* and *SNIP* for *Current Therapeutic Research* had positive correlation coefficients, indicating an increase. In contrast, a negative correlation between *Article* and *Year* (–0.80) indicated a decrease in the number of articles. However, as *Article* decreased before the shift to open access, it cannot be concluded that the shift to open access caused the decrease. All correlation coefficients for *Nuclear Physics B* were negative, and the null hypothesis that they are equal to zero was rejected at the 1% level. Although *Article* decreased in the 2000s before

the shift to open access, it remained almost constant after the shift. Therefore, factors other than the shift to open access may influence the journal's performance. *SJR* and *SNIP* for *Physics Letters B* decreased after the shift to open access, whereas *Article* decreased in the 2000s, in a similar manner to *Nuclear Physics B*. In addition to *Nuclear Physics B* and *Physics Letters B,* SCOAP^3 sponsors the APCs for *Physical Review D*, the *Journal of High Energy Physics*, and *European Physical Journal C*, which are published by research institutes and indexed in Scopus [27]. For the three journals sponsored by SCOAP^3, the null hypothesis that the correlation coefficient between *SNIP* and *Year* between 1999 and 2020 is equal to zero was not rejected at the 10% level. In contrast, the correlation coefficients between *Article* and *Year* for the three journals ranged from 0.80 to 0.98, indicating that the number of articles increased after the shift. Therefore, the results for *Nuclear Physics B* and *Physics Letters B* cannot be generalized to journals related to SCOAP^3. After the shift to open access, *SJR* and *SNIP* for *Stem Cell Research* decreased, whereas *Article* increased significantly. Consequently, academic influence, as measured by the number of citations, increased following the shift to open access.

For *Nucleic Acids Research*, the four indices increased, indicating significant improvements in the journal's performance. However, they increased from 1999 before the shift to open access. Nicholas et al. [30] stated that the Oxford University Press selected this highly prestigious journal to promote open access. An enhanced performance may be attributed to selecting a journal that is expected to improve, rather than to the effect of open access. Although the null hypothesis that the correlation between *SJR* (or *SNIP*) and *Year* for *Nature Communications* is equal to zero was not rejected at the 10% level, *Article* increased significantly. Therefore, the increase in *Citation* can be attributed to the increase in the number of articles. However, as the sample period was short, future trends should be monitored. *SJR* and *SNIP* for the *Journal of Biological Dynamics* increased from the beginning, whereas *Article* remained almost constant. Therefore,

Citation increased because of enhanced citation scores. The four indices for *Health Expectations* increased. The large *Article* during 2013–2015 was attributed to a temporary increase in 2015 (275 articles in 2015). Although *Article* increased after the shift, future trends must be monitored.

(Table 2 near here)

Discussion

Many studies investigated open access advantages by comparing the mean citation scores between open access and non-open access journals. This study found a positive effect of open access when calculating the means of *SJR* and *SNIP* for the eight journals. However, whereas four journals demonstrated positive correlations between *SJR* and *Year* at the 1% level, indicating that *SJR* increased after the shift to open access, three journals had negative correlations at the 1% or 5% level, indicating that *SJR* declined after the shift. In the case of *SNIP*, the eight journals had similar results. Moreover, whereas *Article* for four journals increased at the 1% level, three journals had negative correlations at the 1% level. Thus, an investigation using individual journal data revealed that the effects of open access differed across journals. The difference in results between aggregated data and individual data may be explained by the fact that *Nucleic Acids Research* and *Nature Communications* significantly influenced aggregated data. Since these two journals acquired high citation scores and published many articles, the aggregated values rose significantly. Consequently, the shift to open access of these two journals improved overall journal performance. In the absence of a normal probability distribution for individual indices, the mean is not representative of the sample. This problem persists even when researchers use a large number of observations, as long as the data are highly skewed. In this case, an investigation using aggregated data may lead to misjudgment. Researchers should report the variables' basic statistics and the confidence interval for the mean when using aggregated data. Although this study adopted the third approach,

the issue of data distribution also applies to the first approach.

According to the correlation coefficients, the trends in *SJR* and *SNIP* for *Current Therapeutic Research* and *Stem Cell Research* were opposite to the trends in *Citation*. The findings indicated that the conclusions depended on the choice between citation scores and the number of citations, although many previous studies used either citation scores or the number of citations to examine open access advantages. Furthermore, the correlation coefficients between *SJR* and *Year* as well as between *SNIP* and *Year* differed for *Physics Letters B* (–0.63 and 0.26) and *Nature Communications* (0.35 and –0.03). The findings implied that conclusions also depended on researchers' choice of citation scores, although there is no clear criterion for selecting either *SJR* or *SNIP*. This issue applies to all three approaches.

For *Current Therapeutic Research*, *Stem Cell Research*, and the *Journal of Biological Dynamics*, the correlation coefficients between *SJR* (or *SNIP*) and *Article* differed significantly. Publishers do not generally emphasize the annual number of articles published in a subscription journal; however, the revenues of fully open access journals are heavily dependent on it. Therefore, some publishers may prioritize the number of articles published in open access journals rather than citation scores. Therefore, it is appropriate to use both qualitative and quantitative indices when evaluating publishers' open access strategies.

The performance for *Nucleic Acids Research* was enhanced from before the shift to open access, whereas a decline in the four indices for *Nuclear Physics B* was observed from the beginning of the sample period. A publisher's choice of which journal to shift to open access may influence journal performance after the shift. Regarding the effect of open access articles, Craig et al. [31] pointed out selection bias, that is, which prominent authors are more likely to make their articles available in open access. Similarly, investigation into journal shifts to open access should consider selection bias, that is, the

publisher's choice of which journals to shift to open access.

This study focused on journals launched independently by leading publishers, whereas many studies have included both independently launched journals and those published on behalf of research institutes. If journals for research institutes were included in their samples, their influence might be added. There are several factors that influence open access advantages, which may lead to contradictory conclusions.

Conclusion

This study revisited the methodology used to examine open access advantages and revealed a few problems in previous studies. Although aggregated data indicated that open access enhanced journal performance, the effects differed across journals. Investigations using aggregated data may yield misleading results when the data have a skewed distribution. Furthermore, the results depended on the indices selected by researchers, implying that multiple indices should be used to evaluate publishers' strategies for open access. Additionally, trends of changes in performance for a few journals began before the shift to open access. The findings implied that the effect depended on which journal the publishers chose to shift to open access. Thus, the methodology to determine open access advantages still has room for improvement.

This study has some potential limitations. First, as there were a limited number of journals that met the research requirements, this study investigated only eight journals indexed in Scopus. If it had used Web of Science instead of Scopus, the number would have decreased to seven. It is desirable to investigate more journals to reach reliable conclusions. Second, as most journals shifted to open access in the mid-2010s, not enough time had passed since the shift. If data could be obtained for a longer period, an econometric approach, such as a structural break test, could be applied to identify the effect of the shift to open access. Third, this study used SJR and SNIP as citation scores.

It is possible that different results would have been obtained if it had used other citation indices, such as impact factor and eigenfactor score, which are available from Web of Science. Therefore, it may be useful to compare the results of this study with those using other indices. Further, although this study focused on journals independently launched by for-profit publishers, investigating journals for research institutes may be another topic in the future. It is possible to obtain more journals with longer observation periods several years later. Future studies should include more journals for longer period of time and examine the effect using other indices to confirm the findings of this study.

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Table 1 Outline of journals

Title	Publisher	Start year of open access	Sample period	APC (USD)
Current Therapeutic Research	Elsevier	2013	1999–2020	1,500
Nuclear Physics B	Elsevier	2014	1999–2020	0
Physics Letters B	Elsevier	2014	1999–2020	0
Stem Cell Research	Elsevier	2014	2008–2020	2,100
Nucleic Acids Research	Oxford University Press	2005	1999–2020	3,800
Nature Communications	Springer Nature	2016	2011–2020	5,560
Journal of Biological Dynamics	Taylor & Francis	2012	2008–2020	1,500
Health Expectations	Wiley	2016	2000–2020	2,673

Table 2 Results for journals

Current Therapeutic Research				
Year	*SJR*	*SNIP*	*Citation*	*Article*
1999–2000	0.256	0.268	1,168	90
2001–2003	0.304	0.327	1,118	84
2004–2006	0.220	0.292	1,003	43
2007–2009	0.159	0.230	889	42
2010–2012	0.177	0.287	847	27
2013–2015	0.317	0.350	918	32
2016–2018	0.675	1.014	1,039	16
2019–2020	0.449	0.814	949	39
Correlation	0.54***	0.69***	–0.49**	–0.80***

Nuclear Physics B				
Year	*SJR*	*SNIP*	*Citation*	*Article*
1999–2001	4.682	1.596	60,685	741
2002–2004	4.292	1.622	58,569	544
2005–2007	3.159	1.591	54,448	422
2008–2010	2.793	1.508	52,891	357
2011–2013	2.698	1.466	53,166	305
2014–2016	2.199	1.374	47,589	324
2017–2018	1.527	1.134	40,314	286
2019–2020	1.119	0.944	37,602	310
Correlation	–0.96***	–0.86***	–0.89***	–0.85***

Physics Letters B				
Year	*SJR*	*SNIP*	*Citation*	*Article*
1999–2001	3.497	1.428	84,080	1,399
2002–2004	3.162	1.327	79,531	1,073
2005–2007	3.104	1.555	74,157	952
2008–2010	2.947	1.490	77,937	896
2011–2013	3.359	1.697	84,684	898
2014–2016	3.305	1.801	80,431	863
2017–2018	2.071	1.399	67,187	897
2019–2020	1.944	1.314	65,468	835
Correlation	–0.63***	0.26	–0.48**	–0.79***

Stem Cell Research				
Year	*SJR*	*SNIP*	*Citation*	*Article*
2008–2010	1.695	0.802	161	36
2011–2013	2.019	1.073	953	77
2014–2016	1.952	1.010	2,268	173
2017–2018	0.993	0.646	3,128	234
2019–2020	0.671	0.541	3,881	366
Correlation	–0.68**	–0.44	0.99***	0.94***

Table 2 (continued)

Nucleic Acids Research					*Nature Communications*				
Year	*SJR*	*SNIP*	*Citation*	*Article*	*Year*	*SJR*	*SNIP*	*Citation*	*Article*
1999–2001	4.385	1.533	58,871	749	2011–2012	4.502	2.964	5,398	589
2002–2004	4.508	1.778	64,625	1,032	2013–2015	6.301	2.989	49,941	2,617
2005–2007	4.989	2.016	86,359	1,164	2016–2018	6.329	2.922	188,234	4,678
2008–2010	5.321	1.800	103,753	1,106	2019–2020	5.564	2.950	375,595	6,148
2011–2013	6.369	2.280	135,521	1,338	Correlation	0.35	–0.03	0.96***	0.99***
2014–2016	7.294	2.647	165,873	1,386					
2017–2018	8.831	3.193	188,133	1,392					
2019–2020	8.958	4.229	223,606	1,213					
Correlation	0.94***	0.86***	0.98***	0.68***					
Journal of Biological Dynamics					*Health Expectations*				
Year	*SJR*	*SNIP*	*Citation*	*Article*	*Year*	*SJR*	*SNIP*	*Citation*	*Article*
2008–2009	0.367	0.564	41	36	2000–2003	0.624	0.802	122	35
2010–2011	0.455	0.808	128	42	2004–2006	0.845	1.255	432	39
2012–2014	0.557	0.782	287	38	2007–2009	1.047	1.460	808	41
2015–2017	0.679	1.229	479	36	2010–2012	1.163	1.571	1,252	45
2018–2020	0.716	1.299	813	48	2013–2015	0.954	1.541	1,883	136
Correlation	0.85***,0.82***		0.97***	0.13	2016–2018	1.106	1.315	2,920	127
					2019–2020	1.334	1.763	4,424	149
					Correlation	0.70***	0.67***	0.94***	0.71***

***, **, * indicate significance levels of 1, 5, and 10%, respectively.

Year in bold indicates the start year of open access.