Scientometrics
https://doi.org/10.1007/s11192-020-03836-4

The open access usage advantage: a temporal and spatial analysis

Guangyao Zhang[1] · Yuqi Wang[1] · Weixi Xie[1] · Han Du[1] · Chunlin Jiang[1] · Xianwen Wang[1]

Received: 13 August 2020 / Accepted: 9 December 2020

Abstract
In this study, we compare the article impact in terms of article usage between open access (OA) and non-open access (Non-OA) articles from both the temporal and spatial perspectives. Articles published in *The New England Journal of Medicine* (*NEJM*) were selected as our research objects. Daily article metric data have been tracked and collected from nejm.org and updated every day for over a year. The results of the study confirm the OA usage advantage to a certain extent. OA increases the article views, expands the geographical scope of article readers, and promotes knowledge diffusion. However, the delayed OA policy has no obvious improvement on the OA effects.

Keywords Usage metrics · OA advantage · Immediate OA · Delayed OA

Introduction

"Open Access" (OA), which is taken broadly to mean that research products provided free to the public, has aroused continuous attention for decades. Launched in September 2018 by the European Research Council and major national research agencies and funders from twelve European countries, Plan S requires that, beginning in 2020, scientific publications that result from research funded by public grants must be published in compliant OA journals or platforms. The significance of OA lies not only in the openness and sharing of knowledge, but more importantly, in changing the paradigm of scientific research and the ecology of knowledge communication.

There has been interest in the OA advantage as an important issue (Lawrence 2001; Moed 2007; Joint 2009; Norris et al. 2008; Davis et al. 2008). The OA advantage has been confirmed by many previous studies from the perspective of citations. OA articles are more commonly to be recognized and cited by peers compared with Non-OA articles (Eysenbach 2006; Mccabe and Snyder 2014; Hua et al. 2017; Yan and Li 2018; Wang et al. 2018).

✉ Xianwen Wang
xianwenwang@dlut.edu.cn

[1] WISE Lab Institute of Science of Science and S&T Management, Dalian University of Technology, Dalian, China

Employing article view data and altmetrics data, the OA advantage is further expanded to article usage and social media interests (Wang et al. 2015).

However, previous studies analyzed data from a static perspective and have paid little attention to geographical aspects of the OA advantage. With the continuous enrichment of geographic information from article metric data provided by some journals, e.g., *The New England Journal of Medicine* (*NEJM*), we can explore the OA advantage from both the temporal and spatial perspectives. In this study, we focus mainly on the following two research questions, does OA have an advantage over Non-OA? Including the advantages of article views, geographical spreading and diffusing. Does the delayed OA mechanism have a positive effect in promoting the spread of scientific resources?

Literature review

The geographical perspective in scientometrics

The theories and methods of geography provide a new perspective for solving problems in other disciplines. In scientometrics, measuring regional research activities helps to obtain an overview of the status of active regions and the potential relationships between different regions, so as to understand the geographical pattern of scientific communication and dissemination (Frenken et al. 2009).

Data with geographic information, that is, by adding "where" to information about who is doing what, when, and with whom, is an important component of big data (Thatcher 2014). As for the big data in scientometrics, there have been studies that used Scopus and Web of Science data to draw scientific hot spot maps and analyze the relationship networks between different regions (Bornmann and Leydesdorff 2011; Bornmann and Waltman 2011; Bornmann et al. 2011; Leydesdorff and Persson 2010), and used altmetrics data with specific geographic information, such as Mendeley data, to investigate the geographic reading preferences of readers in different countries (Thelwall and Maflahi 2015; Wang et al. 2016). With the abundance of geographic information inspired by scientific big data, the analysis of scientific data in geographical dimensions is helpful for policy making and the development of science and technology centers (Van Noorden 2010; Liu et al. 2017).

Usage metrics

Besides publication and citation data, using more kinds of metric data to describe the full picture of dissemination and diffusion of science would be valuable (Duy and Vaughan 2006; Priem et al. 2010). With the continuous enrichment of usage data in recent years, the publication of usage data of scholarly papers can have facilitated the timely and effective development of scientific research activities.

The open use of large amounts of usage data enables bibliometric researchers to complete works that traditional bibliometric data (publication data and citation data) could not (Liu et al. 2009, Liu and Zhu 2012; Chen et al. 2017). Article usage data are widely used to investigate user behavior (Davis and Price 2006; Davis and Solla 2003), detect and track research trends (Wang et al. 2013a) and evaluate research outcomes (Davis et al. 2008). After merging geographic coordinate information, article usage data is able to reflect different user behaviors in different regions (Wang et al. 2012, 2013b). As a result, article usage data provides a new method for revealing research activities and knowledge dissemination

in geographic space. For example, based on different visiting patterns of the old and new papers, the geographical distribution of the papers is analyzed to discover the diffusion process of knowledge (Fang et al. 2017).

Open access and geographical diffusion of knowledge

OA promotes the diffusion of knowledge and has an important impact on developing countries' access to scientific resources. Some studies have found that the influence of OA is more than twice as strong in the developing world by using more extensive citation data (Evans and Reimer 2009). OA has citation advantage in Africa and Asia (Tang et al. 2017), and OA has a positive effect on promoting scholarly communication on health in Africa (Ezema and Onyancha 2017). As to geographic variation in relation to Altmetrics, some studies have used the data from SciELO and Altmetric.com to contribute to the understanding of how the potential of altmetrics varies around the world, in which they measure the percentage of articles with non-zero metrics (coverage) for articles published from a developing region (Latin America) and find the levels of coverage by the major altmetrics sources are generally lower than what has been previously reported. (Alperin 2015). However, people from emerging countries cannot obtain articles as immediately as developed countries after publication (Fang et al. 2017). Therefore, there are still problems to be clarified: Can emerging countries benefit from delayed OA?

With the availability of unique article metric data released by *NEJM*, including page views and their geographical distribution for each article and updated daily, it is possible for us to examine the OA advantage from both temporal and spatial perspectives. Compared with the previous analysis applying static article metric data (Wang et al. 2015; Fang et al. 2017; Chen 2017; Holmberg et al. 2019), we have tracked and collected the daily updated article metric data over 1 year, to observe the full process and draw the full picture of (temporal and geographical) diffusion of scholarly articles.

Data and method

Article metrics of NEJM

In this study, articles published in *NEJM* are selected as the test bed. *NEJM* is a weekly medical journal and among the most prestigious peer-reviewed medical journals as well as the oldest continuously published one, since 1812.

There are several major reasons why we chose *NEJM* as our research objective. Firstly, the website of *NEJM*, nejm.org provides article metrics for each published item since July 2010. As Fig. 1 shows, the metric data includes Page Views (including html and pdf views), Citations, Global Media Coverage and Social Media. More importantly, the metrics also display the geographical distribution of page views through an interactive global map, which makes the metric data quite unique and possible for us to study the OA advantage from a spatial perspective. Secondly, *NEJM* publishes both immediate OA and delayed OA articles, so a comparative analysis can be made between the two kinds of papers. Thirdly, 6 months (180 days) after publication, *NEJM* makes full texts of all articles free of charge on nejm.org, which is called delayed OA. Therefore, we can evaluate the change in article views before and after the OA of articles from a temporal perspective.

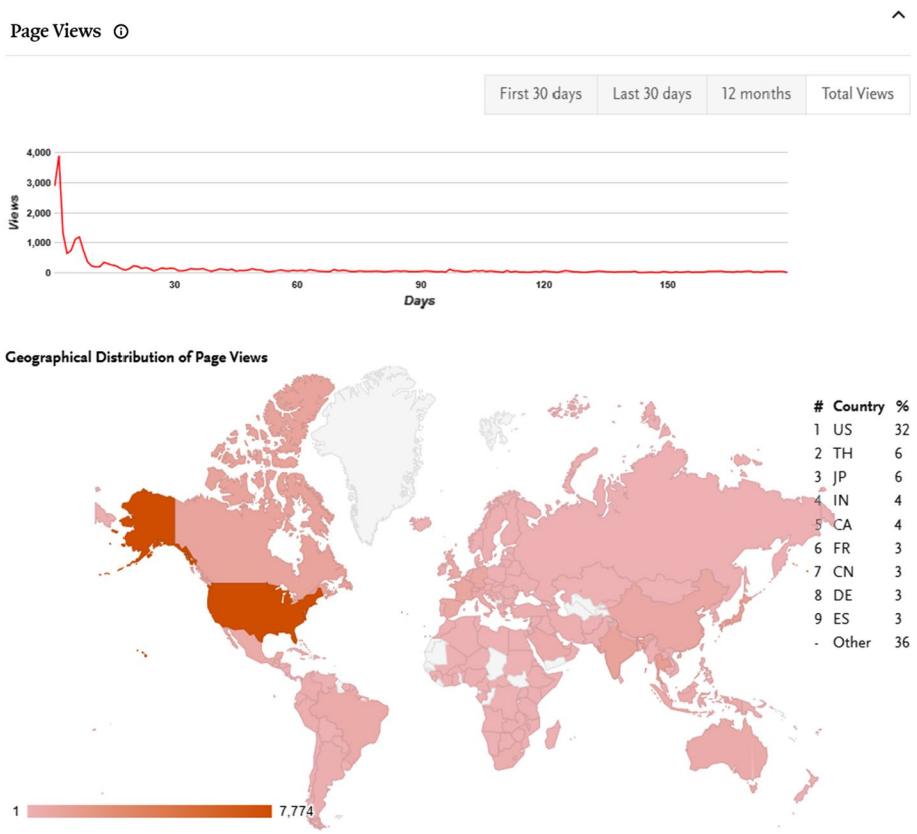


Fig. 1 Metrics of a *NEJM* article (https://www.nejm.org/doi/metrics/10.1056/NEJMoa1714284)

Data collection and processing

We limited the types of articles to four types of Research, Review, Cases and Perspective. We excluded 31 papers with abnormal metric data, because these papers have many reads before they are published on nejm.org. To ensure that all the articles have enough time to accumulate the metric data, we collected the metric data for 377 days and updated the data daily, which is from January 11, 2019 to January 23, 2020 for 421 articles, including the daily updated page views and geographical distribution data. We selected those articles with a published history over 240 days of publication as the data set, including 99 Non-OA articles and 66 OA articles.

The data collected and updated daily were combined to obtain 11,579,906 pieces of data, and 7,144,227 pieces were kept after excluding the data of the papers published after May 23, 2019 because of the time window of 240 days. There are 8772 items without geographical information in the data set, with the maximum value of 52 and the total page views accounting for less than 0.01% of the total views of the data set. Excluding these flawed data would not affect the reliability of the research. Thus, 7,135,455 items were finally kept. On the basis of the data set, the published date and publication status (OA or Non-OA) of the articles were tagged and the viewed days of articles were calculated (the

collection date of the metric data minus the published date of the article), and then those data with viewed days less than 240 were excluded, resulting in 5,434,929 items in the dataset. The country and region codes were transformed from ISO 3166-1 alpha-2 to ISO 3166-1 alpha-3 starting from the date of June 25, 2019, so we unified country and region codes in the dataset into ISO 3166-1 alpha-3. We identified 28 developed countries and incorporated the country type information (Developed Countries/Emerging Countries) into the data set, according to Human Development Report 2010 (UNDP 2010).

We can explain our data tracking procedures in detail using Fig. 2. We started tracking data on January 11, 2019 and tracked it until January 23, 2020. We named January 23, 2020 the "final day". Nejm.org has weekly updates for its newest published papers, so we add new papers to our data set every week. Paper A was published on the first day and the data spanned 377 days. Paper B was published on March 29, 2019 and lasted for 300 days. Similarly, the duration of papers C/D/E is 240/180/120 days, respectively. Papers whose duration is less than 240 days are deleted from the data set, and a total of 165 (99 + 66) papers are retained. The first 240 days of data from these 165 papers were uniformly retained for further study.

Results

The advantages of page views on OA

We calculated the cumulative views of OA and Non-OA articles respectively and compared the results at five time points, as Table 1 shows. All the median value of cumulative views of OA is greater than of Non-OA articles. Figure 3 shows the comparison results of article views between OA and Non-OA articles for each week. The median value of cumulative article views for OA articles is much greater than for Non-OA articles.

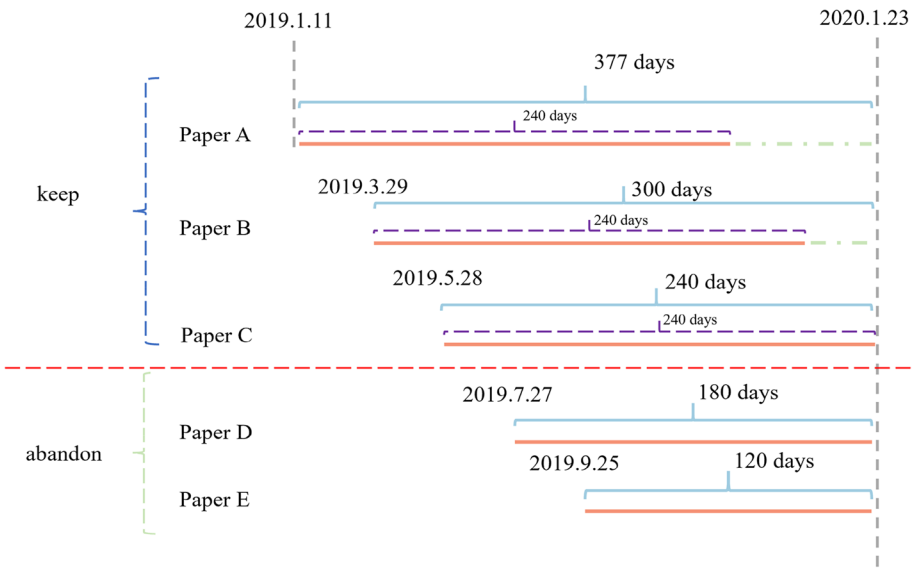


Fig. 2 Explanation of data tracking procedures

Table 1 Comparison of cumulative page views between OA and Non-OA articles

Published days	Cumulative page views (median)		
	OA	Non-OA	OA/Non-OA
1	1684	1600	1.05
7	7555	6888	1.10
30	11,958	8910	1.34
180	17,298	11,510	1.50
240	20,307	11,919	1.70

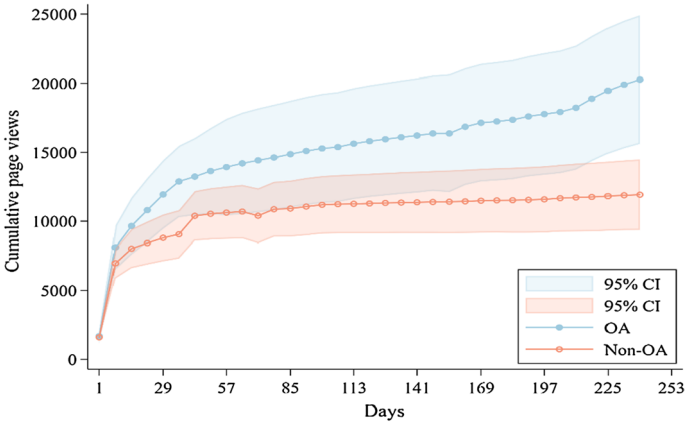


Fig. 3 Comparison of cumulative page views between OA and Non-OA articles

The geographical diffusion advantages of OA

H index is defined as "A scientist has index h if h of his or her Np papers have at least h citations each and the other $(Np-h)$ papers have fewer than $\leq h$ citations each", which has been favored by researchers for its practicality and simplicity (Hirsch 2005). Similarly, geographical h index is designed to measure the advantages of article views in terms of geographical diffusion. Geographical H index is defined as "A paper has geographical h index if h of its Np countries have at least h views each and the other $(Np-h)$ countries have fewer than $\leq h$ views each." We calculated the cumulative number of countries which have article views and geographical H index, as Table 2 shows. The 240-day data in cumulative countries is abnormal, but it does not affect the geographical advantages of OA. As shown in Figs. 4 and 5, the OA curve is higher than the Non-OA curve in terms of the cumulative number of countries and geographical H index.

Next, we used the Herfindahl–Hirschman Index (HHI) (Herfindahl 1950) to reflect the diffusion ability of articles in the time dimension. The HHI is often used to characterize the distribution of a variable of interest by measuring its degree of concentration across units. Its advantage is that it can consider all the information of individuals in a collection and is often used to measure the market concentration of the industry. The formula is defined as:

Table 2 Comparison of cumulative number of countries and geographical H index between OA and Non-OA articles

Published days	Cumulative number of countries			H index		
	OA	Non-OA	OA/Non-OA	OA	Non-OA	OA/Non-OA
1	75	75.5	0.99	16	14	1.14
7	125	122	1.02	29	27	1.07
30	139	134	1.04	33.5	30	1.12
180	147	140	1.05	38	33	1.15
240	146.5	139	1.05	39	34	1.15

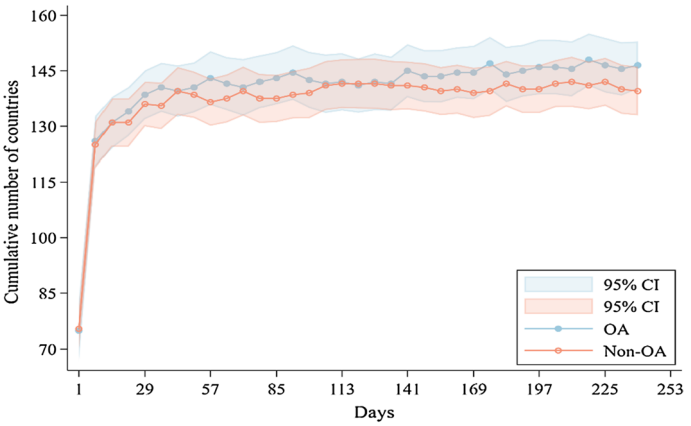


Fig. 4 Comparison of cumulative number of countries between OA and Non-OA articles

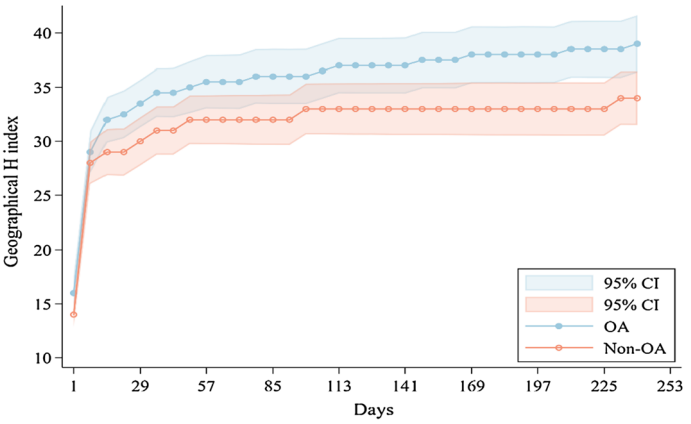


Fig. 5 Comparison of geographical H index between OA and Non-OA articles

$$\mathrm{HHI} = \sum_{n=1}^{k} (S_n)^2 = \sum_{n=1}^{k} \left(\frac{views_{m,n}}{views_n} \right)^2 \quad (1)$$

where $views_{m,n}$ is the average article views per article in a country in a day, $views_n$ is the sum of $views_{m,n}$ of all countries in a day. S_n indicates the ratio for average article views in the n_{th} country to the sum of average article views.

The high HHI means that the page views are concentrated in a few countries. When the page views of articles are completely concentrated in one country, HHI takes 1. As shown in Fig. 6, the HHI is plotted on the primary (left) axis, and the line of Non-OA articles (orange line) is higher than OA (blue line). To facilitate comparison, we calculated the ratio of HHI and plotted it on the secondary (right) axis. In addition, a reference line is drawn at the position where the ratio is 1. HHI rapidly reached its peak within 2 days after publication and showed a trend of continuous fluctuation and decline with the passage of time, indicating that the degree of "monopoly" of articles is declining. At least in the first 120 days, Non-OA(HHI) was significantly higher than OA(HHI), indicating that the diffusion ability of Non-OA articles was significantly weaker than the OA articles.

Comparison between two periods of before-OA and after-OA

NEJM provides delayed free online access to its research articles, and it does so 6 months after publication. To measure the effect of delayed OA on the diffusion of articles, does it increase article views when Non-OA articles convert to OA after 180 days of publication? We took the 180th day as the dividing point and observed the changes in article views in 150–210 days. As shown in Fig. 7, the median of daily cumulative article views is in the range of 11,393–11,712, and there was no obvious difference after becoming OA. Similarly, we observed the changes in the number of countries, as shown in Fig. 8, where the median of daily countries is in the range of 139–142, and the results are similar to article views with no obvious differences.

We calculated the daily average article views from emerging countries during the before-OA period (60 days) and after-OA period (60 days). For the before-OA period, we count days from back to front; but for the after-OA period, we count days from front to back. As shown in Fig. 9, even if the status of articles changes to OA, there is no difference in page views between after-OA and before-OA periods. Tests were further conducted

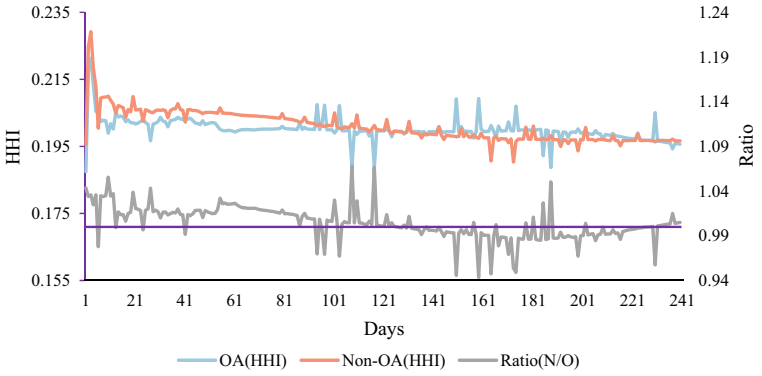


Fig. 6 Comparison of geographical diffusion between OA and Non-OA articles

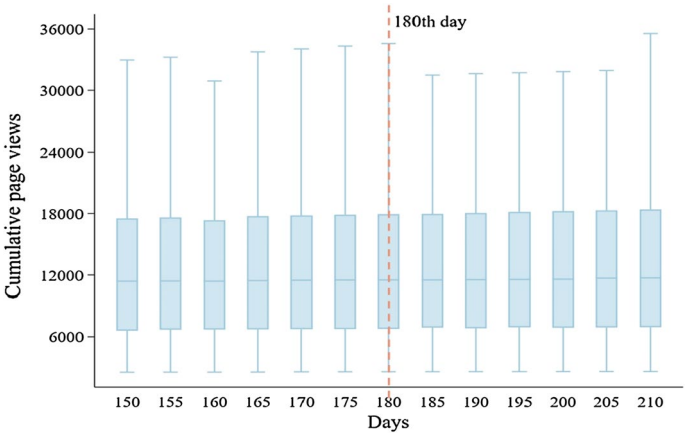


Fig. 7 Comparison of cumulative page views between before-OA and after-OA

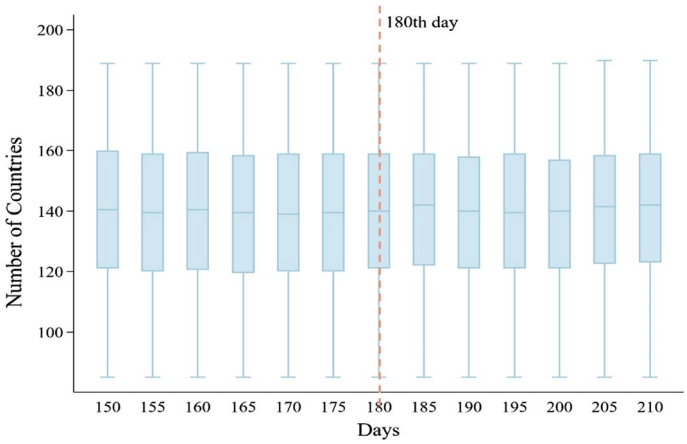


Fig. 8 Comparison of countries between before-OA and after-OA

to verify the statistical difference between before-OA and after-OA periods. The data for article view from before-OA period to after-OA period does not meet the normal distribution assumption (before-OA p value = 0.000, after-OA p-value = 0.000 based on the Shapiro–Wilk test), so we conducted a permutation test and proved that there is no significant difference in article view between before-OA and after-OA ($p = 0.121$).

Comparison of new and old articles

We used cumulative page views on day 30 of publication of papers as benchmark values (D_{30}), and articles published between February 22, 2017 and February 21, 2019 were selected to make analysis. These articles were divided into two groups. That is, the articles published between February 22, 2017 and February 21, 2018 (Y_{23}) were used to observe the usage performance of articles published within 2–3 years, and the articles published

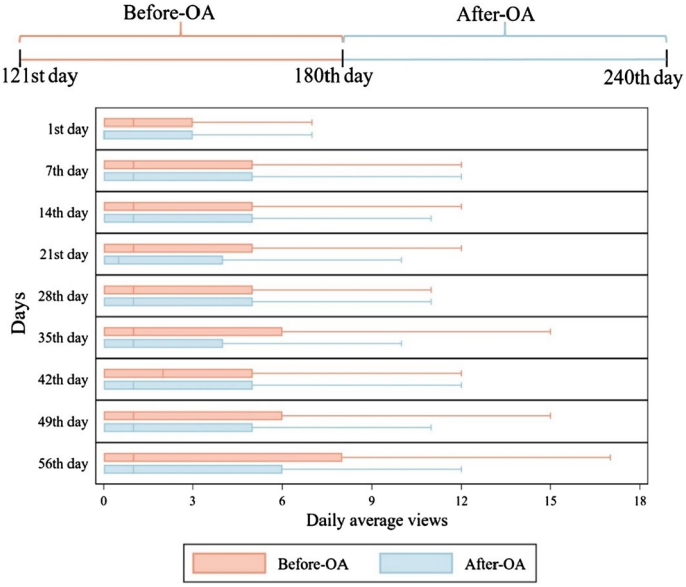
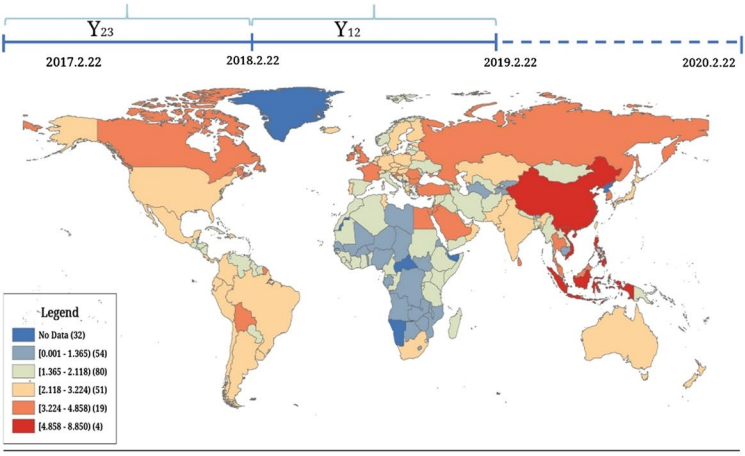


Fig. 9 Comparison of daily article views in emerging countries between before-OA and after-OA

during February 22, 2018–February 21, 2019 (Y_{12}) were used to observe the usage performance of articles published within 1–2 years.

We calculated the ratio of Y_{12} to D_{30} and Y_{23} to D_{30} on average article views respectively to compare the usage performance between the old and new papers. The greater the ratio, the fewer views for new articles, which means it takes a longer time for the region to read the newly published papers. As shown in Fig. 10, such as Y_{12}, the top 10 countries are all emerging countries and the color in east and southeast Asia is dark red, which indicates



Rank	Nation	Ratio
1	PHL	8.85
2	VNM	7.47
3	CHN	6.85
4	IDN	6.48
5	RUS	4.86
6	BGR	4.70
7	MYS	4.68
8	LKA	4.39
9	SAU	4.26
10	SGP	3.98

Fig. 10 Ratio of Y_{12} to D_{30} in average article views

that these countries have limited access to articles at the initial stage after publication and that article views don't rise to a certain level until a long time period after publication. We can also notice that the color is mostly blue in most parts of Africa, that is, for the least developed countries, the situation of accessing to new and old articles has not changed much, and there are great restrictions on reading scholarly papers in these least developed countries. As for Y_{23}, the results are similar to Y_{12}.

Conclusion and discussion

In this study, employing the metric data provided by *The New England Journal of Medicine*, we confirmed the OA advantages from both temporal and spatial perspectives. Compared with Non-OA, OA articles have higher page views and have faster geographical diffusion in more countries. There is a diffusion process in the clicking of scholarly articles, and the diffusion ability of OA articles is higher than that of Non-OA, which shows that OA is effective in attracting more readers and breaking the monopoly of scholarly resources. Although the delayed OA came into effect 180 days after publication, there is no obvious difference in terms of article views and number of countries which have article views between two periods of before-OA and after-OA, which suggests that the delayed OA does not bring more readers from developing or emerging countries. Readers from developed countries can access the newly published articles within a short time after publication, while readers from emerging countries have disadvantages in accessing scholarly resources quickly. Only after a long period of time when articles were published, can readers from emerging countries access them. Even though there is a policy of allowing low-income countries to obtain free full-text (NEJM 2020), low-income countries that meet the policy standards still have a very low number of page views, which may be affected by the overall scientific research strength of the country or the poor digital infrastructure. But at this time, the timeliness of new discoveries embedded in the newly published papers has been greatly reduced. Delayed OA has a limited effect on the diffusion of scientific knowledge.

OA has played a great role in spreading scholarly resources and breaking down barriers to accessing knowledge. Although the delayed OA has taken a solid step in the OA movement, its main purpose is still to protect the interests of publishers. As a result, it affects the timeliness of scientific resources for readers from developing regions. The best way to promote the dissemination and utilization of scientific resources is immediate OA, which is the final realization mode of the OA movement, which also promotes the dissemination of scientific knowledge, and further enhances the influence of periodicals. But it's obvious that implementing immediate OA faces new challenges, the most conspicuous of which is expensive costs. It is meaningless to talk about OA without considering the cost. OA established a new paywall between journal and author after removed a paywall that constrains readers' access. The development of OA and the improvement of publishing mode should be consistent (Carling et al. 2018).

Limitation

The reasons why *NEJM* chose to publish in the form of OA, such as public interest and the authors' funding support, were not considered, which caused some limitations in the exclusion of various factors. Authors' affiliation, research scope and international collaborations

may also influence article metrics. The article views data reflect only the article usage on the nejm.org journal platform, not including article usage data from other platforms or services (e.g., arXiv, Sci-Hub).

Acknowledgements We gratefully acknowledge the Grant from the National Natural Science Foundation of China (71673038, 71974029).

References

Alperin, J. P. (2015). Geographic variation in social media metrics: An analysis of Latin American journal articles. *Aslib Journal of Information Management, 67*(3), 289–304.

Bornmann, L., & Leydesdorff, L. (2011). Which cities produce more excellent papers than can be expected? A new mapping approach, using Google Maps, based on statistical significance testing. *Journal of the American Society for Information Science and Technology, 62*(10), 1954–1962.

Bornmann, L., Leydesdorff, L., Walch-Solimena, C., et al. (2011). Mapping excellence in the geography of science: An approach based on Scopus data. *Journal of Informetrics, 5*(4), 537–546.

Bornmann, L., & Waltman, L. (2011). The detection of "hot regions" in the geography of science: A visualization approach by using density maps. *Journal of Informetrics, 5*(4), 547–553.

Carling, J., Bivand, E. M., Harstad, B., et al. (2018). Plan S: At the crossroads of open access to research: An assessment of the possible consequences of Plan S for publishing, research quality and research environments. Peace Research Institute Oslo and Faculty of Social Sciences. Oslo: University of Oslo.

Chen, B. (2017). Usage pattern comparison of the same scholarly articles between Web of Science (WoS) and Springer. *Scientometrics, 115*(1), 519–537.

Chen, Y., Wang, Z. Q., Tan, J. G., & Liu, Z. Y. (2017). The position of preprint in scholarly communication: A bibliometric and empirical study of ArXiv. In I. Atanassova, M. Bertin, & P. Mayr (Eds.), *The 16th international conference on scientometrics and informetrics* (pp. 799–809). Wuhan: ISSI, Wuhan University.

Davis, P. M., Lewenstein, B. V., Simon, D. H., et al. (2008). Open access publishing, article downloads, and citations: Randomised controlled trial. *BMJ: British Medical Journal, 337*(7665), 343–345.

Davis, P. M., & Price, J. S. (2006). eJournal interface can influence usage statistics: Implications for libraries, publishers, and Project COUNTER. *Journal of the American Society for Information Science and Technology, 57*(9), 1243–1248.

Davis, P. M., & Solla, L. R. (2003). An IP-level analysis of usage statistics for electronic journals in chemistry: Making inferences about user behavior. *Journal of the American Society for Information Science and Technology, 54*(11), 1062–1068.

Duy, J., & Vaughan, L. (2006). Can electronic journal usage data replace citation data as a measure of journal use? An empirical examination. *Journal of Academic Librarianship, 32*(5), 512–517.

Evans, J. A., & Reimer, J. (2009). Open access and global participation in science. *Science, 323*(5917), 1025.

Eysenbach, G. (2006). Citation advantage of open access articles. *PLoS Biology, 4*(5), 692–698.

Ezema, I. J., & Onyancha, O. B. (2017). Citation impact of health and medical journals in Africa: Does open accessibility matter? *Electronic Library, 35*(5), 934–952.

Fang, Z. C., Guo, X. H., Yang, Y., et al. (2017). Measuring global research activities using geographic data of scholarly article visits. *Electronic Library, 35*(4), 822–838.

Frenken, K., Hardeman, S., & Hoekman, J. (2009). Spatial scientometrics: Towards a cumulative research program. *Journal of Informetrics, 3*(3), 222–232.

Herfindahl, O. C. (1950). Concentration in the steel industry. Ph.D. thesis, Columbia University.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America, 102*(46), 16569–16572.

Holmberg, K., Hedman, J., Bowman, T. D., Didegah, F., & Laakso, M. (2019). Do articles in open access journals have more frequent altmetric activity than articles in subscription-based journals? An investigation of the research output of Finnish Universities. *Scientometrics, 122*(1), 645–659.

Hua, F., Sun, H., Walsh, T., et al. (2017). Open access to journal articles in oncology: current situation and citation impact. *Annals of Oncology Official Journal of the European Society for Medical Oncology, 28*(10), 2612–2617.

Joint, N. (2009). The Antaeus column: Does the "open access" advantage exist? A librarian's perspective. *Library Review, 58*(7), 477–481.

Lawrence, S. (2001). Free online availability substantially increases a paper's impact. *Nature, 411*(6837), 521.

Leydesdorff, L., & Persson, O. (2010). Mapping the geography of science: Distribution patterns and networks of relations among cities and institutes. *Journal of the American Society for Information Science and Technology, 61*(8), 1622–1634.

Liu, Z. Y., Chen, C. M., Hou, H. Y., et al. (2009). Towards an epoch of great changes of science studies. *Science of Science and Management of S.& T., 30*(07), 5–12. **(in Chinese)**.

Liu, Z. Y., Chen, Y., & Song, C. (2017). Global innovation center: Origin, meaning and conditions. *China SciTechnology Business, 10,* 52–58. **(in Chinese)**.

Liu, Z. Y., & Zhu, X. Y. (2012). Measuring and mapping of international scientometrics and its sister disciplines. *Science & Technology Review, 30*(07), 68–79. **(in Chinese)**.

Mccabe, M. J., & Snyder, C. M. (2014). Identifying the effect of open access on citations using a panel of science journals. *Social Science Electronic Publishing, 52*(4), 1284–1300.

Moed, H. F. (2007). The effect of "open access" on citation impact: An analysis of ArXiv's condensed matter section. *Journal of the American Society for Information Science and Technology, 58*(13), 2047–2054.

NEJM. (2020). Access in low-income countries. Accessible at https://www.nejm.org/about-nejm/access-in-developing-countries. Accessed November 2020.

Norris, M., Oppenheim, C., & Rowland, F. (2008). The citation advantage of open-access articles. *Journal of the American Society for Information Science and Technology, 59*(12), 1963–1972.

Priem, J., Taraborelli, D., Groth, P., et al. (2010). Altmetrics: A manifesto. http://altmetrics.org/manifesto/. Accessed 27 February 2020.

Tang, M., Bever, J. D., & Yu, F. H. (2017). Open access increases citations of papers in ecology. *Ecosphere, 8*(7), e01887. https://doi.org/10.1002/ecs2.1887.

Thatcher, J. (2014). Living on fumes: Digital footprints, data fumes, and the limitations of spatial big data. *International Journal of Communication, 8*(1), 1765–1783.

Thelwall, M., & Maflahi, N. (2015). Are scholarly articles disproportionately read in their own country? An analysis of Mendeley readers. *Journal of the Association for Information Science and Technology, 66*(6), 1124–1135.

UNDP. (2010). Human Development Report 2010: The Real Wealth of Nations - Pathways to Human Development. New York. http://hdr.undp.org/en/content/human-development-report-2010.

Van Noorden, R. (2010). Cities: Building the best cities for science. *Nature, 467*(7318), 906–908.

Wang, X. W., Chen, L., Mao, W., et al. (2015). The open access advantage considering citation, article usage and social media attention. *Scientometrics, 103*(2), 555–564.

Wang, X. W., Cui, Y. X., Xu, S. M., et al. (2018). The state and evolution of Gold open access: A country and discipline level analysis. *Aslib Journal of Information Management, 70*(5), 573–584.

Wang, X. W., Fang, Z. C., Li, Q. C., & Guo, X. H. (2016). The poor altmetric performance of publications authored by researchers in Mainland China. *Frontiers in Research Metrics and Analytics*. https://doi.org/10.3389/frma.2016.00008.

Wang, X. W., Peng, L., Zhang, C. B., et al. (2013a). Exploring scientists' working timetable: A global survey. *Journal of Informetrics, 7*(3), 665–675.

Wang, X. W., Wang, Z., & Xu, S. M. (2013b). Tracing scientist's research trends realtimely. *Scientometrics, 95*(2), 717–729.

Wang, X. W., Xu, S. M., Peng, L., et al. (2012). Exploring scientists' working timetable: Do scientists often work overtime? *Journal of Informetrics, 6*(4), 655–660.

Yan, E., & Li, K. (2018). Which domains do open-access journals do best in? A 5-year longitudinal study. *Journal of the Association for Information Science and Technology, 69*(6), 844–856.