Why highly cited articles are not highly tweeted? A biology case

Zhang, Liwei; Wang, Jue

2018

Zhang, L., & Wang, J. (2018). Why highly cited articles are not highly tweeted? A biology case. *Scientometrics*, 117(1), 495–509. doi:10.1007/s11192-018-2876-6

<https://hdl.handle.net/10356/140870>

<https://doi.org/10.1007/s11192-018-2876-6>

© 2018 Akadémiai Kiadó. All rights reserved. This paper was published by Springer Nature in *Scientometrics* and is made available with permission of Akadémiai Kiadó.

Downloaded on 26 Apr 2023 18:15:26 SGT

Why highly cited articles are not highly tweeted? A biology case

Liwei Zhang¹ and Jue Wang^{2*}

¹ WISE Lab, Dalian University of Technology, Dalian 116085, China.

² School of Social Sciences, Nanyang Technological University, Singapore.

* corresponding author: WangJue@ntu.edu.sg

Abstract

Altmetrics is an emerging topic that has generated much interest. Most of the studies, however, have focused on the comparison of altmetric indicators with traditional citation metrics and few have explored the factors influencing altmetric performance. This study investigates the dissemination pattern of scientific articles on social media and particularly focused on highly tweeted articles and highly cited articles. Based on bibliometric and altmetric data collected for over 40000 articles in the field of biology, we found the timing of tweets and the type of Twitter accounts affect the amount of attention that a scientific publication receives on social media. Articles with a high number of tweets are generally the ones receiving immediate social media exposure and are often tweeted by journal associated organization accounts or other individual accounts with a high number of followers. By contrast, highly cited articles in general are neither tweeted timely nor promoted by their respective journal accounts.

Keywords: publication; citation; tweet; Twitter users; timing of tweet

Introduction

Scientific communication does not only refer to the communication between scientists, but also between scientists and the general public. The latter is often known as science education or popular science (Bernal, 1939). In 1985, the British Association for the Advancement of Science (BAAS), the Royal Institution and the Royal Society together established the Committee on the Public Understanding of Science (COPUS), and published the report *Public understanding of science*. The mission of COPUS to disseminate scientific advances and make science more accessible to non-scientists has played an important role in helping the public understand science (Ziman, 1991). The dissemination of science has turned out to be a task not only for government, but for every individual scientist as well (Massey, 1989). Correspondingly, it was proposed to include a component on societal impact in the evaluation of scientific research. The UK funding agency believes that research evaluation should include “all kinds of social, economic and cultural benefits and impacts beyond academia, arising from excellent research” (HEFCE, 2011). Lutz Bornmann (2017) also called for an evaluation beyond measuring impact on science alone, but on all sectors of society. However, it has yet to receive much attention in evaluation practice (Bornmann, 2013). Traditional citation impact metrics still dominate evaluation exercises and these metrics fail to capture the societal impact. Therefore, scholars have been working toward a new method to measure the societal impact of science (Bornmann, 2014b), one that is feasible and economically viable (Frank & Nason, 2009). The popularization of social media since the last decade has provided a new venue for sharing scientific knowledge directly with the public, and allows for capturing digital footprints of these articles and study their societal impact, as a way of complementing the traditional citation measures in the scientific community (Moed, 2016).

While there are various digital tools and platforms for science communication, such as Mendeley (Thelwall & Wilson, 2015), ResearchBlogging (Shema, Bar-Ilan, & Thelwall, 2014), F1000 (Mohammadi & Thelwall, 2013), and ResearchGate (Thelwall & Kousha, 2015), their use is mostly confined among scientists and does not reach out to the public, and hence does not serve the purpose of measuring the societal impact. Altmetrics, a short form for “Article-Level Metrics”, appears to be a better alternative. It was developed to distinguish article level metrics from ones at the journal level (Neylon & Wu, 2009). Later in 2012, Priem et al. (2012) started the site Altmetric.com to count all the mentioning of research output on social media, especially on Twitter and Facebook. Altmetrics since then has received great attention in the scientific community as it points to a new direction to study research impact (Wouters & Costas, 2012). Bornmann (2014c) shows that altmetrics is tailored for a readership beyond the confines of science, and the results promisingly demonstrated that altmetric data (tweets counts) have the potential to identify papers with societal impact. Some literature are concerned with the changes of scientific dissemination, such as new forms of communication (e.g., research blogs) and the reduced delay in dissemination (Bornmann, 2014a; Fenner, 2014; Priem, Groth, et al., 2012). More studies pay attention to the comparison between altmetrics and the citation metrics as well as the application of altmetrics in research evaluation. The analysis of the relationship between altmetrics and citations suggests that these two metrics are weakly related, with the former capturing societal impact while the latter focused on scientific impact (Bar-Ilan et al., 2012; Costas, Zahedi, & Wouters, 2015; Haustein, Peters, Sugimoto, Thelwall, & Larivière, 2014; Ortega, 2016; Priem, Piwowar, & Hemminger, 2012; Sud & Thelwall, 2014; Thelwall, Haustein, Larivière, & Sugimoto, 2013; Zahedi, Costas, & Wouters, 2014). However, it was also noted that the weak correlation between the two could be attributed by the highly skewed distribution of citations and tweets with a large set of publications

that are neither cited nor tweeted (Fei Shu & Haustein, 2017; Fei Shu, Lou, & Haustein, 2018). In fact, after accounting for the distribution problem, Shu and his colleagues (2017; 2018) found Twitter exposure was associated with the increase of citations.

Given the confounding findings on the relationship between citations and social media exposure, the study intends to move further in this direction and explore whether highly cited articles are generating equally high interest on social media, and if not, why. While citation counts are found to be related to a number of factors (Bornmann, Schier, Marx, & Daniel, 2012) such as the reputation of the journal (Callaham, Wears, & Weber, 2002) and authors (Peters & van Raan, 1994), group authorship (Glänzel & Schubert, 2001), sources of funding (Wang & Shapira, 2015), as well as respective disciplines (Neuhaus & Daniel, 2009), less attention has been paid to social popularity of a scientific article, with a few exceptions such as Chapa et al. (2017) that examines the association between the design of clinical trials and the subsequent attention received from social media. This study intends to compare the dissemination pattern of highly cited articles with that of socially popular articles and explore factors behind the level of attention an article receives on social media. Given the critical role of central nodes in network group communication (Bavelas, 1948, 1950; Freeman, 1978; Leavitt, 1951) and instant response time in information diffusion on social media (Petrovic et al., 2013; Subašić & Berendt, 2011; Zhao et al., 2011), we will particularly look into the users who are circulating the articles and the timing of the posts.

Data and Method

The study uses two types of data: bibliometric data based on publications from the Web of Sciences (WoS), and altmetric data based on Tweets from Altmetric.com. Compared with users of other social media, Twitter users are found to be more interested in scientific publications and are

more likely to disseminate science related information via retweet (Xia et al., 2016). Therefore, this study uses tweet data for analyzing the impact of scientific research on social media.

Bibliometric data are comprised of evolutionary biology articles published since the 1st January 2010 until 24th May 2017, the date of data retrieval, with a total of 41,004 articles. The subject category of evolutionary biology was selected as it was the field appealing to a wider public audience (Bornmann, 2014c). We only include articles after 2010 as only since then the altmetric data were available on Altmetric.com (Priem, Taraborelli, Groth, & Neylon, 2010). Bibliometric information such as the title, the journal, the publication date, DoI, keywords and total citations (TC) of each article were recorded for each article. Among the 41,004 articles, 1,361 were found without DoI information. Next, we retrieved altmetric data for the remaining 39,643 articles on Altmetric.com using the DoI of each article, and identified 21,495 articles mentioned on Twitter with a total of 190,283 tweets. For each tweet, we recorded the date of the tweet and the profile of the Twitter account.

The accumulation pattern for tweets was rather distinct from the patterns for citations. While citations take time to accumulate, tweets appear to be more promptly. For instance, 98% of articles published in 2011 have citations, but only 17% of those published in 2017 received citations (Figure 1a). The longer time window provides more opportunities for publications to be cited. This is not the case with tweets. 78% of articles published in 2017 were mentioned on Twitter, in contrast with only 9% of those published in 2011. Twitter users respond quickly to newly released research findings and tend to less care about studies published years ago. For example, 73% of tweets in 2017 mentioned publications in the same year (2017), and 12% were referring to research published in the previous year (2016). Only less than 15% of the tweets were discussing articles published before 2016. The popularity of new publications on Twitter also corresponds to

the widening user base in recent years. A similar pattern can be observed from the average numbers of total counts for citations and tweets for publications in different years (Figure 1b). While articles published in 2010 received on average 48.57 citations and 4.89 tweets, the 2017 articles only had 0.23 citations but 14.42 tweets. Extracting only highly tweeted articles (with at least 50 tweets; total 485 articles) and highly cited articles (with at least 50 citations; total 1,288 articles), we again observed a similar relationship. Highly tweeted articles were mostly published in recent years (2015, 2013, 2017 and 2016), while most of highly cited articles were published much earlier (in 2011, 2013, 2010 and 2012) (Figure 1c and 1d).

Figure 1 somewhere here

We then proceeded to compare the characteristics of highly cited articles and highly tweeted articles. The 41,004 articles in our dataset come from 48 journals. The highly cited articles are usually published on *Molecular Biology and Evolution* (IF2016=6.2) and *Systematic Biology* (IF2016=8.9) – journals with high impact factors (Table 1). By contrast, highly tweeted articles appear to be on journals such as *Proceedings of the Royal Society B: Biological Sciences* (IF2016=4.94) and *Genome Biology and Evolution* (IF2016=4), ones not necessary with the highest impact factors. It shows the rank of the journal is not as influential in guiding the scientific interest on social media.

Table 1 somewhere here

Twitter users are classified by Altmetrics.com into four categories: members of the public, scientists, practitioners, and science communicators, based on users' profile information on the Twitter¹. Here we have to acknowledge that the classification may not be very accurate as the

¹ 1) Member of the public: someone who does not link to scholarly literature and does not fit any of the categories below.

2) Scientist: someone who is familiar with the literature.

3) Practitioner: a clinician or researcher who is working in clinical science.

4) Science communicator: someone who links frequently to scientific articles from a variety of different journals or publishers.

Twitter account information is self-reported. A total of 132 Twitter accounts were found missing classification information. The highly tweeted articles were mostly mentioned by the public, accounting for over half of all the tweets, whereas the highly cited articles were mostly tweeted by scientists and the circulation was still within the scientific community (Figure 2). It seems while these highly cited articles generated high interest among scientists, be it in the form of citations or tweets, they failed to reach the public and were not as popular on social media.

Figure 2 somewhere here

Analysis

In order to investigate why some articles are generating interests among the public and others are not, we constructed two smaller sets of highly tweeted articles (thereafter as HTAs) and highly cited articles (HCAs). HTAs are comprised of articles that were mentioned in at least 100 tweets by 2017, which leads to a total of 117 articles. The dataset of HCAs includes 30 top cited articles (but being tweeted at least once) for each year during 2011-2017, with a total of 210 articles. We chose articles with at least one tweet as we need to study why they were popular/unpopular on the Twitter (not why they didn't appear on the Twitter at all). An equal number of articles every year was selected to better control time effect on citation accumulation. It is less a concern for altmetrics as tweets emerge more quickly (usually within a year; also see elaboration below). Table 2 shows the comparison between HTAs and HCAs in 2011-2017. In 2011, each HTA received 186.3 tweets on average, more than 83 times of HCAs. The gap was reduced in more recent years as the HCAs were tweeted more than before. Likewise, the average citation counts for HTAs were only 2% of that for HCAs in 2011, but were around 25% in 2017 with a smaller gap, which might be due to the fact that citation accumulation takes time. Recent few years do not provide enough

time window to receive citations and therefore HCAs do not differ as much from the rest of articles.

Table 2 somewhere here

Timing of tweets

We then extracted the timing of tweets for both HTAs and HCAs, especially the first tweet, as well as the date of publication (more specifically the date it appearing online, e.g., online first), which allows us to compute the time lag between publication and the first tweet. The tweets were counted for four time intervals: within one month of publication, 2-6 months, 7-12 months and more than one year. The majority of tweets for HTAs occurred within one year, and mostly within one month (Figure 3). We also highlighted the bursted tweeted points – days with at least 10 tweets – as red dots in the figure, and found them mostly occur immediately following the first tweet. It shows if an article is not generating high interest soon after the first post, it is likely that it will not generate interest at all.

Figure 3 somewhere here

Same conclusion can be reached if we compare the time delay between publication and the first tweet for the two sets of articles. For HTAs since 2013, as shown in Table 3, majority of them were tweeted on the day of publication and there was no time delay between their appearing on scientific journals and social media. The rest were mostly were tweeted within 7 days of publication. By contrast, less than half of HCAs in recent years and even fewer in 2011-2013 appeared on the Twitter the same day of publication. It again clearly shows that an article being twitted immediately after publication is more likely to receive attention on the Twitter.

Table 3 somewhere here

Twitter users

The 190,283 tweets received by these articles were contributed by 42,858 Twitter users, among whom 40 users were active tweeters with at least 300 tweets (Table 4). The top users included @OfficialSMBE (1,856 tweets), @EcoEvoJournals (1,378 tweets), @cbjones1943 (1,220 tweets) and @RSocPublishing (859 tweets). A co-referrer network map of all the users with at least 30 tweets based on co-occurrence matrix reveals active users as core nodes in the referrer network – the red, blue and yellow nodes in Figure 4. There are mainly two types of active users: official accounts (for journals, societies, organizations etc) and individual users with a large number of followers.

Figure 4 somewhere here

With the rapid development of social media, an increasing number of scientific journals have set up Twitter accounts to publicize their publications, including some of the source journals in this study (Table 4). For example, @OfficialSMBE is the official Twitter account for the Society for Molecular Biology and Evolution (SMBE), which owns the journal of *Molecular Biology and Evolution* and the journal of *Genome Biology and Evolution*. Similarly, the Royal Society has two Twitter accounts – @RSocPublishing and @royalsociety, and owns the journal *Proceedings of the Royal Society B: Biological Sciences* and *Biological Letters*. These journal-associated Twitter accounts play a big role in advertising scientific publications on Twitter. Majority of the HTAs were from journals with Twitter accounts, such as *Proceedings of the Royal Society B*, *Biological Letters* and *BMC Evolutionary Biology*. These articles were often first tweeted by their journal-associated accounts and then quickly got spread out. Journal associated Twitter accounts are generally regarded as being reputable due to their official status and all have a big number of followers. For example, the article “Can a collapse of global civilization be avoided?” (DOI 10.1098/rspb.2012.2845) published on the journal *Proceedings of the Royal Society B* was first

tweeted by the account @royalsociety on the day of publication, and subsequently received 932 tweets (Table 5). By contrast, HCAs were rarely tweeted by their journal accounts or their journals don't even have Twitter accounts.

Table 4 somewhere here

Table 5 somewhere here

The other type of users as core nodes in the network was popular users – individual accounts with a large number of followers. For example, users such as @uranus_2 and @razibkhan have more than 80 thousand followers. Articles tweeted by these users will be read by a big audience and can quickly get broadcasted. Again we compare the two sets of articles with the number of tweets from popular users. In 2011, on average each HTA was tweeted by 41.67 users who had more than 2,000 followers, but each HCA was only mentioned by 0.83 such users on average (Table 6). Similarly, around 4 users with over 25 thousand followers had tweeted each HTA, but only 0.1 for each HCA. The difference was relatively smaller in more recent years but still striking.

Table 6 somewhere here

Discussion

With the popularization of social media, scientific publications are increasingly having societal impact, but interestingly, articles receiving great attention on social media are not necessary the ones highly regarded by scientists. This study intends to explore the factors behind the difference in dissemination between popular articles in the scientific community (indicated by high citations) and on social media (indicated by high tweets) and found two relevant factors: the timing of tweets and the users who tweeted. It complements previous studies on predictors of social

media coverage (Chapa et al., 2017) by introducing factors on media posting, comparing trends over multiple years and using a broader scope of journals.

The study makes use of the bibliometric and altmetric data collected for 41,004 publications in the field of evolutionary biology. By analyzing the delay between publication and the first tweet, it is clear that tweets are time sensitive. Latest news are more likely to generate interest on social media. Majority of the HTAs were tweeted on the same day of the publication, and most tweets were posted within one year. HCAs did not receive a high number of tweets, partly because they were not tweeted timely. Only a small share of HCAs appeared on the Twitter on the same day of publication, while half of them waited over a year to receive the first tweet. The average time delay between tweets and publication for HCAs was more than 16 times of that for HTAs. The findings imply that the sooner an article receives tweets, the more tweets it will accumulate afterwards.

The profile of users who tweeted the articles also points to interesting findings. Twitter accounts with a large number of followers and journal-associated accounts have made great contribution to the accumulation of tweets. Tweets posted by these accounts are more visible and reputable, and are more likely to be picked up by other users and circulated further. HTAs were usually tweeted by journal-associated accounts and popular individual accounts. By contrast, HCAs were rarely tweeted by their respective journal accounts or accounts with a good number of followers.

To summarize, HCAs that are not highly tweeted are associated with two observations: 1) they are not immediately mentioned on social media and 2) they are not actively promoted by their respective journals. Our study again confirms that scientific impact is not equivalent with societal impact, and our findings have practical implications for improving societal impact of scientific

research. Journals need to be proactive in promoting their publications. It is strongly advisable for journals to set up their own Twitter accounts and build up their visibility by gaining more followers. Given the importance of timely dissemination, journals should tweet the research immediately when it is available and make it known to the public. For authors who wish to promote their research, maintain active Twitter accounts and have a good follower base will be helpful. In addition, the circulation needs to go beyond the network of scientists and get the general public involved, preferably ones who are influential with active posting and active followers.

Of course, we have to point out that the study is limited in its scope. It only uses a sample of research articles in a single field of evolutionary biology and cannot readily generalize the findings to all disciplines. Future studies can expand the scope to test whether the pattern holds across disciplines. In addition, this study only examines the dissemination of scientific findings on Twitter, which might be different from other social media platform. It will be interesting to contrast tweeting with the sharing on other social media such as Facebook or LinkedIn. Lastly, the study is only a first step exploring the factors behind the popularity of scientific articles on social media. There might be other factor beyond those mentioned in this article that can be influential and can be examined in future studies.

Acknowledgements

We would like to thank Altmetric.com for granting access to altmetrics data.

References

- Bar-Ilan, J., Haustein, S., Peters, I., Priem, J., Shema, H., & Terliesner, J. (2012). Beyond citations: Scholars' visibility on the social web. *arXiv*, 1205.5611.
- Bavelas, A. (1948). A mathematical model for group structures. *Human organization*, 7(3), 16-30.

- Bavelas, A. (1950). Communication patterns in task-oriented groups. *Journal of the Acoustical Society of America*, 22(6), 723-730.
- Bernal, J. D. (1939). *The social function of science*. London: Routledge & Kegan Paul Ltd.
- Bornmann, L. (2013). What Is Societal Impact of Research and How Can It Be Assessed? A Literature Survey. *Journal of the American Society for Information Science and Technology*, 64(2), 217–233.
- Bornmann, L. (2014a). Do altmetrics point to the broader impact of research? An overview of benefits and disadvantages of altmetrics. *Journal of Informetrics*, 8(4), 895-903.
- Bornmann, L. (2014b). Is there currently a scientific revolution in scientometrics? *Journal of the Association for Information Science and Technology*, 65(3), 647–648.
- Bornmann, L. (2014c). Validity of altmetrics data for measuring societal impact: A study using data from Altmetric and F1000Prime. *Journal of Informetrics*, 8(4), 935-950.
- Bornmann, L., & Haunschild, R. (2017). Does evaluative scientometrics lose its main focus on scientific quality by the new orientation towards societal impact? *Scientometrics*, 110(2), 937–943.
- Bornmann, L., Schier, H., Marx, W., & Daniel, H.-D. (2012). What factors determine citation counts of publications in chemistry besides their quality? *Journal of Informetrics*, 6(1), 11-18.
- Callaham, M., Wears, R. L., & Weber, E. (2002). Journal prestige, publication bias, and other characteristics associated with citation of published studies in peer-reviewed journals. *JAMA*, 287(21), 2847–2850.
- Chapa, J., Haq, Z., & Cifu, A. S. (2017). Comparative analysis of the factors associated with citation and media coverage of clinical research. *Scientometrics*, 112(3), 1271-1283.
- Costas, R., Zahedi, Z., & Wouters, P. (2015). Do “altmetrics” correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective. *Journal of the Association for Information Science and Technology*, 66(10), 2003-2019.
- Fenner, M. (2014). Altmetrics and other novel measures for scientific impact *Opening science* (pp. 179-189): Springer International Publishing.
- Frank, C., & Nason, E. (2009). Health research: measuring the social, health and economic benefits. *Canadian Medical Association Journal*, 180(5), 528-534.
- Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social networks*, 1(3), 215-239.
- Glänzel, W., & Schubert, A. (2001). Double effort= double impact? A critical view at international co-authorship in chemistry. *Scientometrics*, 50(2), 199-214.
- Haustein, S., Peters, I., Sugimoto, C. R., Thelwall, M., & Larivière, V. (2014). Tweeting biomedicine: an analysis of tweets and citations in the biomedical literature. *Journal of the American Society for Information Science and Technology*, 65(4), 656–669.
- HEFCE. (2011). *Decisions on assessing research impact*. Bristol, UK: Higher Education Funding Council for England.
- Leavitt, H. J. (1951). Some effects of certain communication patterns on group performance. *The Journal of Abnormal and Social Psychology*, 46(1), 38-50.
- Massey, W. E. (1989). Science education in the United States: What the scientific community can do. *Science*, 245(4921), 915-921.
- Moed, H. F. (2016). Altmetrics as traces of the computerization of the research process. In C. R. Sugimoto (Ed.), *Theories of informetrics and scholarly communication. A Festschrift in Honor of Blaise Cronin* (pp. 360–371). Berlin: De Gruyter.
- Mohammadi, E., & Thelwall, M. (2013). Assessing non-standard article impact using F1000 labels. *Scientometrics*, 97(2), 383–395.
- Neuhaus, C., & Daniel, H.-D. (2009). A new reference standard for citation analysis in chemistry and related fields based on the sections of Chemical Abstracts. *Scientometrics*, 78(2), 219–229.

- Neylon, C., & Wu, S. (2009). Article-level metrics and the evolution of scientific impact. *PLoS Biology*, 7(11), e1000242.
- Ortega, J. L. (2016). To be or not to be on twitter, and its relationship with the tweeting and citation of research papers. *Scientometrics*, 109(2), 1353-1364.
- Peters, H. P. F., & van Raan, A. F. J. (1994). On determinants of citation scores – A case study in chemical engineering. *Journal of the American Society for Information Science*, 45(1), 39–49.
- Petrovic, S., Osborne, M., McCreadie, R., Macdonald, C., Ounis, I., & Shrimpton, L. (2013). Can twitter replace newswire for breaking news? *Proceedings of the Seventh International AAAI Conference on Weblogs and Social Media*, 713–716.
- Priem, J., Groth, P., & Taraborelli, D. (2012). The altmetrics collection. *PloS one*, 7(11), e48753.
- Priem, J., Piwowar, H. A., & Hemminger, B. M. (2012). Altmetrics in the wild: Using social media to explore scholarly impact. *arXiv*, 1203.4745.
- Priem, J., Taraborelli, D., Groth, P., & Neylon, C. (2010). Altmetrics: A manifesto. Retrieved from <http://altmetrics.org/manifesto>
- Shema, H., Bar-Ilan, J., & Thelwall, M. (2014). Do blog citations correlate with a higher number of future citations? Research blogs as a potential source for alternative metrics. *Journal of the Association for Information Science and Technology*, 65(5), 1018-1027.
- Shu, F., & Haustein, S. (2017). On the citation advantage of tweeted papers at the journal level. *Proceedings of the Association for Information Science and Technology*, 54(1), 366–372.
- Shu, F., Lou, W., & Haustein, S. (2018). Can Twitter increase the visibility of Chinese publications? *Scientometrics*, DOI: 10.1007/s11192-018-2732-8.
- Subašić, I., & Berendt, B. (2011). Peddling or creating? investigating the role of twitter in news reporting. *Advances in Information Retrieval. Lecture Notes in Computer Science*, 6611, 207-213.
- Sud, P., & Thelwall, M. (2014). Evaluating altmetrics. *Scientometrics*, 98(2), 1131-1143.
- Thelwall, M., Haustein, S., Larivière, V., & Sugimoto, C. R. (2013). Do altmetrics work? Twitter and ten other social web services. *PloS one*, 8(5), e64841.
- Thelwall, M., & Kousha, K. (2015). ResearchGate: Disseminating, communicating, and measuring scholarship? *Journal of the Association for Information Science and Technology*, 66(5), 876–889.
- Thelwall, M., & Wilson, P. (2015). Mendeley readership altmetrics for medical articles: an analysis of 45 fields. *Journal of the Association for Information Science and Technology*, 67(8), 1962-1972.
- Wang, J., & Shapira, P. (2015). Is There a Relationship between Research Sponsorship and Publication Impact? An Analysis of Funding Acknowledgments in Nanotechnology Papers. *PloS one*, 10(2), e0117727. DOI: 0117710.0111371/journal.pone.0117727.
- Wouters, P., & Costas, R. (2012). *Users, narcissism and control: tracking the impact of scholarly publications in the 21st century*. Utrecht: SURFfoundation.
- Xia, F., Su, X., Wang, W., Zhang, C., Ning, Z., & Ivan, L. (2016). Bibliographic Analysis of Nature Based on Twitter and Facebook Altmetrics Data. *PloS one*, 11(12), e0165997.
- Zahedi, Z., Costas, R., & Wouters, P. (2014). How well developed are altmetrics? A cross-disciplinary analysis of the presence of 'alternative metrics' in scientific publications. *Scientometrics*, 101(2), 1491-1513.
- Zhao, W. X., Jiang, J., Weng, J., He, J., Lim, E. P., Yan, H., & Li, X. (2011). Comparing twitter and traditional media using topic models. *European Conference on Information Retrieval. Lecture Notes in Computer Science*, 6611, 338-349.
- Ziman, J. (1991). Public understanding of science. *Science, Technology, & Human Values*, 16(1), 99-105.