Quantitative portrait of open access mega-journals

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ABSTRACT

Nowadays, Open Access Mega-Journals (OAMJs) represent a substantial part of the scholarly communication system. The current research is conducted with the aim of providing better insights into the increasingly important OAMJ phenomenon through investigation of eight reputable titles using established bibliometric methods. Results of the study showed that eight studied OAMJs were responsible for 1.87% of the total number of publication indexed in Web of Science during 2012-2016. Despite the decline in publication count of PLOS ONE over the past couple of years, it was the biggest journal in the world till 2017, when Scientific Reports overtook PLOS ONE as the most productive journal. Over 88% of the papers published in eight selected OAMJs were cited at-least once at the point in time of analysis. The highest proportions of cited and un-cited documents were seen in Scientific Reports and SpringerPlus, respectively. With regard to the three indicators, namely share of highly-cited papers, the category normalized citation impact as well as the JIF percentile, IEEE Access had by far the best performance among eight examined OAMJs. Results of the study revealed that Biochemistry & Molecular Biology, Multidisciplinary Sciences, Neurosciences, Oncology and Immunology were the most commonly assigned subject categories to OAMJs' content. The National Natural Science Foundation of China was the most important funding agency that supported the publication of around 26000 articles in eight studied OAMJs. Investigation of the geographic distribution of authors showed that the United States and China by far had the highest contribution in the content of eight studied OAMJs. There were, however, notable variations between different OAMJs.

Keywords: Mega-journals; Open access journals; Scholarly communication; Journal studies; Bibliometrics.

INTRODUCTION

Today, a significant proportion of scientific articles are being published in Open Access (OA) journals. In December 2016, the Directory of Open Access Journals (DOAJ, available at www.doaj.org) listed more than 9400 fully OA journals and this increasing trend is expected to continue. Of the 22, 256 journals indexed by Elsevier's Scopus in 2015, gold OA journals comprised approximately 17 percent of the total titles (Erfanmanesh 2017). Many advantages of OA publishing are mentioned in the literature, including wider distribution of scientific content, higher visibility and accessibility, unrestricted free and permanent access to the results of publicly funded studies and public dissemination of research findings (Solomon 2008). Over the past decade, new approaches have emerged in scholarly publishing ecosystem; notable amongst these are the "Open Access Mega-Journals" (hereafter OAMJs). OAMJs represented increasingly substantial venues for dissemination of research output and science communications. Björk (2015) has identified four primary characteristics of the OAMJs: (a) large publication volume, (b) objective peer review based

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on the scientific soundness of the content only (rather than its novelty, significance and relevance), (c) broad scope of scientific disciplines and sub-disciplines and (d) publishing model based on the pre-publication article processing charges (APCs). He also noted a series of secondary criteria that commonly exhibited in OAMJs, including the fast review and publishing process, the reusability of figures and data, the use of article-level metrics for post-publication evaluation, the availability of commenting functionality, and the high acceptance rate (Björk 2015).

PLOS ONE, the very first OAMJ, was launched in 2006 by the Public Library of Science. *PLOS ONE* started operation with the publication of 137 documents in 2006 and reached 21,145 outputs in 2017. This exponential growth has resulted in *PLOS ONE* published almost 0.83 percent of the total indexed publications in Clarivate Analytics' Web of Science (WoS) during 2006-2017. Submitted manuscripts to the *PLOS ONE* go through a peer-review process that concentrates only on technical soundness and research method of the work – it is left to the scientific community to judge its perceived importance, significance, contribution and impact of the publication using article-level metrics such as download statistics, page views, social media mentions and readership counts (Spezi et al. 2018). *PLOS ONE*'s phenomenal success along with the financial potential of the OAMJ publishing market has motivated other prestigious publishers such as Nature, Sage, Taylor & Francis, Wiley-Blackwell, BMJ, Elsevier and Springer to launch their own PLOS-style OAMJs or to convert their subscription-based traditional journal into an OAMJ. Another motivating factor for the establishment of an OAMJ by scientific publishers was the possibility of cascading papers rejected by the publishers' highly-selective journals to their OAMJ for consideration. In many cases, authors are given a choice by journal editors to submit their papers to the publisher's OAMJ after it was rejected by other more selective journals of the same publisher (Solomon 2014).

The scientific community has shown different and somewhat controversial views with regard to the OAMJ phenomenon. Some believe that OAMJs facilitate the publication of articles that might not easily find their spot in highly-selective journals. The fact is that a considerable proportion of the articles published in OAMJs had been rejected by other journals. Surveying authors published in OAMJs, Solomon (2014) found that 37 percent of the *PeerJ* outputs were resubmissions of manuscripts previously rejected. Binfield (2013) estimated that 15 million hours are wasted each year in the peer-review process and submit-reject cycle. Some believe that OAMJs have the potential to democratizing knowledge, facilitating open science, improving the efficiency and accelerating the speed of the scholarly communication system. In contrast, others criticize the quality control of the OAMJs' content which caused bulk publishing of low quality outputs and difficult-to-publish materials. They argue that the removal of pre-publication judgment for significance and impact of the content would likely result in information overload as well as information pollution (Spezi 2017).

OAMJ publishing is a relatively new and growing phenomenon with relatively sparse academic literature. Limited empirical studies have yet been carried out regarding various aspects of OAMJ phenomenon. The current research attempts to investigate the characteristics of selected OAMJs and analyze their output using bibliometric approaches and indicators. The specific objectives of the current research were to examine the:

(a) General characteristics of the OAMJs,
(b) Publishing trend and market share of the OAMJs,
(c) Bibliometric performance of the OAMJs,
(d) Funding agencies supporting articles published in the OAMJs,
(e) Disciplinary scope of articles published in the OAMJs,

(f) Geographic distribution of articles published in the OAMJs, and
(g) Mega-authorship phenomenon in articles published in the OAMJs.

LITERATURE REVIEW

This review highlights a few studies on OAMJs in order to understand better the phenomenon and its implications for scholarly communication. The emerging and successful model of scholarly OA publishing has led Beall (2013) to review five predatory mega journals which appeared to imitate the characteristics of legitimate OAMJs, namely *British Journal of Science, International Journal of Current Research, International Journal of Science and Advanced Technology, International Journal of Sciences* and *World Journal of Science and Technology.* Content, pricing options, user interface and contract provisions of these five journals were evaluated critically. In his survey of 2,128 authors who had published in four OAMJs (*BMJ Open, PeerJ, PLOS ONE* and *Sage Open*), Solomon (2014) reported that the quality of the journals, the OA publication of the output, the speed of the peer-review and publication process, the Journal Impact factor (JIF) and reputation of the publishers were the most significant factors influencing authors' decision to submit manuscripts to the OAMJs in which they published. Results showed that the majority of authors were satisfied with the experience of publishing in OAMJs and affirmed that they would probably submit to the same or a similar OAMJ again. Moreover, it was reported that approximately half of the papers published in OAMJs had previously been rejected by a conventional journal.

Björk (2015) investigated the characteristics of 14 OAMJs in terms of output volumes, publication charges, acceptance rates and publishing speed. Results of the study showed that the overall number of articles published in the selected OAMJs grew from 6,913 in 2010 to 33,872 in 2015. The APCs of the journals studied varied from USD195 for *SAGE Open* to USD1950 for *G3*. The OAMJs were found to have relatively low rejection rates, ranged from 31 percent of all submissions for *PLOS ONE* to 49 percent for *Biology Open*, while the rejection rate for high-prestige science, technology and medicine (STM) journals is more than 90 percent. Moreover, the average turn-around time from submission to publication was estimated to be around 3-5 months in different OAMJs. In Björk's (2015) study, a series of primary and secondary criteria were presented to characterize OAMJs. In another research, Burns (2015) studied a sample of 49 papers published during the first several months after the launch of *PeerJ* as an OAMJ. Results of the study showed that internationally co-authored papers constituted about 43 percent of all publications. Download statistics, page views and social media attentions were found to be high after articles are published, but declined sharply thereafter. Moreover, no statistically significant differences were observed in the speed of peer-review process between articles that were submitted before and after the journal's transition from a traditional subscription-based journal to an OAMJ. Björk and Catani (2016) compared citation performance of several OAMJs with a group of highly-selective conventional journal in the same subject category to investigate the citation advantage of OAMJ publishing system. The results showed little differences in citation distribution of papers published in the two groups of journals. They concluded that the novel form of peer-review in OAMJs that seek only to evaluate objectively the scientific and technical soundness of the content, does not lead to less future citation impact of the papers.

Wakeling et al. (2016) conducted a bibliometric study of articles published in 11 OAMJs to analyze four key characteristics of these journals, namely the number of published articles, author nationalities and institutional affiliations, the disciplinary scope and the citation

distribution of each journal. The findings of this study indicated that articles published in the studied OAMJs in 2015 accounted for nearly 2.5 percent of all articles indexed by the Elsevier's Scopus. Wakeling et al. (2016) also reported considerable differences in geographical distribution of authors published in OAMJs, with some OAMJs are clearly more popular in specific countries. Authors affiliated with institutions in the USA were the largest contributors to six out of the 11 OAMJs, while three OAMJs, namely *AIP Advances, Medicine* and *Scientific Reports* disproportionately had a high proportion of Chinese authors. In another research, Shopovski and Marolov (2017) studied the most important reasons influencing authors of the *European Scientific Journal*'s decision to publish in OAMJs. Results of the study revealed that recommendations of colleagues, quality editorial board, OA publication model and fast peer-review process were the most encouraging factors to submit their manuscript to OAMJs.

Shin (2017) studied the contribution of South Korean researchers in 12 OAMJs. Results revealed that the proportion of articles published by South Korean authors in OAMJs increased from 2.3 percent of total output of the country in 2006 to 2.77 percent in 2015. Moreover, the average annual growth rates of OAMJ article publications by South Korean authors were shown to be higher than that of the world. Wakeling et al. (2017a) compared scholarly output, citation performance and author characteristics of the journal *Medicine* prior to and following its transition from a highly-selective traditional journal to an OAMJ in 2014. Results showed a dramatic rise in the annual output of the *Medicine* after it began operating as an OAMJ, resulting in this journal the 6th largest medical sciences journal title indexed in WoS in 2016. However, *Medicine's* JIF dropped significantly from 5.7 before adoption of the OAMJ model to 2.1 after its transition to the OAMJ model. Additionally, comparing the 20 most common citing journals to the *Medicine's* articles revealed that these documents are being cited in journals with lower JIFs in post-transition period compared with the pre-transition period.

In a qualitative study, Wakeling and colleagues reported the results of interviews with 31 publishers and editors with regard to the OAMJ phenomenon in a two-part paper. In the first part of the paper, they reported seven motivating factors for launching OAMJs (Wakeling et al. 2017b). Facilitating the publication of articles that might otherwise not be published, experimenting innovative approaches in scholarly communication, supporting the open science movement, addressing inefficiencies in the scientific publishing system, generating more revenue for publishers, simplifying the cascade of manuscripts rejected by the publisher's more selective journals, and emerging market opportunities were thought by publishers and editors to drive the launch on an OAMJ. In the second part of the paper, Wakeling et al. (2017c) discussed the publishers and editors' perspectives on cultural, operational and technical challenges associated with OAMJs. Developing a positive reputation in the scientific community, obtaining a high JIF, supporting the publisher's expenses by OAMJs' APC revenue, marketing OAMJs to academia, charging high APCs and managing rapid growth of OAMJs were reported by editors and publishers as potential challenges of OAMJ phenomenon.

Spezi et al. (2017) reviewed the available literature relating to OAMJ phenomenon and studied four primary criteria of OAMJs identified by Björk (2015), i.e. high publishing volume, soundness-only peer-review, broadly defined disciplinary coverage, and APC-based OA publishing. Each of these criteria was investigated in prominent OAMJs, such as *PLOS ONE* and *Scientific Reports*. In a longitudinal study of publication volumes, Björk (2018) investigated the evolution of 19 OAMJs during 2006-2017. He divided OAMJs into four groups based on their proportional publication volumes., namely the *Big Two* (*PLOS ONE*

and *Scientific Reports*), *Converted Journals* (*Medicine*), *Middle Tier* (e.g. *SpringerPlus* and *IEEE Access*) and *Smaller Journals* (e.g. *Sage Open* and *Heliyon*). The results revealed a considerable shift in the origin of authors who published in OAMJs over time especially for those affiliated with Chinese institutions. The proportions of Chinese authored articles were more than half of all documents published in *IEEE Access* and *Medicine* in 2017.

Arising from the two-year empirical investigation of the OAMJ phenomenon (Wakeling et al. 2017a; 2017b), Spezi et al. (2018) reported on the findings related specifically to "soundness-only" peer review model for OAMJs. Definition of the "soundness-only" peer-review approach, differences with traditional pre-publication review and operational realities of this model were discussed in detail based on interviews with the senior editors and publishers. Findings showed that although OAMJs claim an objective review based on a paper's scientific and technical soundness, however in many cases, reviewers still bring subjective factors such as significance, novelty and impact into their evaluation of articles under review. Although a few number of studies had been conducted on OAMJ phenomenon over the past years especially by B.C. Björk, D.J. Solomon and a team of researchers from Loughborough University and University of Sheffield, however more research needs to be done on different aspects of the OAMJ publishing in order to understand better the phenomenon. The previous research has focused on the definition and features of OAMJs, author surveys on factors affecting their OAMJ selection, the peer-review process in OAMJs, bibliometric performance of the OAMJs as well as case studied on individual journals. The current research differs from previous bibliometric studies on OAMJs (Björk 2015, 2018; Wakeling et al. 2016; Shin 2017) in a number of ways including the selected OAMJs, the studied research objectives, the analyzed time frame and the investigated indicators.

MATERIALS AND METHOD

The study was conducted using bibliometric approach. It was based on the data collected from three Clarivate Analytics' products, namely the Web of Science (WoS), Journal Citation Reports (JCR) and InCites. At the beginning, a list of active OAMJs which had been identified in previous studies (Binfield 2013; Björk 2015, 2018; Wakeling et al. 2016) was prepared. Estimates of the number of the OAMJs in operation varied extensively in different resources, ranged from 14 (Björk 2015) to 28 (Binfield 2013). Some criteria considered for the journal selection in this study include indexation status in the WoS, publication by reputable scientific publishers and attainment of JIF in the JCR. Accordingly, eight OAMJs which satisfied all of the criteria were selected for the final investigation. It was thought that the selected titles could offer a representative picture of the OAMJ publishing system. The eight OAMJs included *PLOS ONE, Scientific Reports, BMJ Open, SpringerPlus, PeerJ, IEEE Access, Biology Open* and *FEBS Open Bio*. The time span under analysis was limited to five years. All 195,011 documents published by the selected OAMJs during 2012-2016 and indexed in the WoS were selected for investigation, thus no sampling was conducted. Data were obtained in September 2018 and contained citation data of the studied journals until the point in time of data gathering. Data analysis and visualization was performed using Microsoft Excel. Moreover, geographic heatmap was illustrated with Microsoft Power Map for Excel. With regard to the fifth objective of the study, it is noteworthy that journals were assigned to one or two subject categories in WoS and each published item will inherit all subject categories assigned to the parent journal. This method would be challenging in the study of OAMJs as these journals publish articles on a wide range of topics. Recently, Clarivate Analytics' InCites introduced a new approach to algorithmically reassign each document published in the categories of "Multidisciplinary Science" and "Medicine, General and Internal" to its most

relevant subject area using the information found in the cited references of each publication (InCites Benchmarking & Analytics 2018).

RESULTS

General Characteristics of the OAMJs

The general characteristics of the eight OAMJs are detailed in Table 1. As the disciplinary scope of the OAMJs can be seen Table 1, four out of the eight studied OAMJs (*PLOS ONE*, *Scientific Reports*, *SpringerPlus* and *PeerJ*) cover the full spectrum of the science, technology and medicine (STM) disciplines, while by contrast other OAMJs cover broad subject areas (*BMJ Open* for Medicine, *Biology Open* for Biology, *FEBS Open Bio* for Biochemistry and Molecular Biology). *IEEE Access* is the only OAMJ that publish articles exclusively in the areas of Computer Sciences, Electrical Engineering and Telecommunications. All of the eight selected OAMJs were launched by highly reputable and established scientific publishers. *PeerJ* is the only OAMJ under investigation which is not operated by a large publishing house. *PLOS ONE* was the first OAMJ, founded in 2006, and has been followed by four other journal titles in 2011 (*Scientific Reports, BMJ Open, Biology Open* and *FEBS Open Bio*), one title in 2012 (*SpringerPlus*) and two titles in 2013 (*PeerJ* and *IEEE Access*). It should be noted that *SpringerPlus* ceased publication from 2017 onwards due to the publisher's decision. Seven out of the eight studied OAMJs are published in the United States and the United Kingdom; indicate the dominating role of these two countries in OAMJ publishing. The APCs of the journals studied ranged from USD1095 (*PeerJ*) to USD 1770 (*BMJ Open*).

Table 1: General Characteristics of the OAMJs Considered in This Study

Journal	Publisher	Subject Area (JCR)	Country	Start	APC (USD)
PLOS ONE	Public Library of Science	Multidisciplinary Sciences	US	2006	1595
Scientific Reports	Nature Publishing Group	Multidisciplinary Sciences	UK	2011	1760
BMJ Open	BMJ Publishing Group	Medicine, General & Internal	UK	2011	1770
SpringerPlus	Springer Int. Publishing	Multidisciplinary Sciences	Denmark	2012	1290
PeerJ	PeerJ Inc	Multidisciplinary Sciences	UK	2013	1095
IEEE Access	IEEE	Computer Science, Information Systems Engineering, Electrical & Electronics Telecommunications	US	2013	1750
Biology Open	Company of Biologists	Biology	UK	2011	1495
FEBS Open Bio	Wiley-Blackwell	Biochemistry, Molecular Biology	US	2011	1750

Publishing Trend and Market Share of the OAMJs

Table 2 shows the number of documents published during 2012-2016 along with the total number of outputs in each of the eight selected OAMJs. The overall output to the end of 2016 of all eight OAMJs under study was 195,011, of which 50,732 documents were published in 2016. The overall publications of the eight OAMJs accounted for the 1.87 percent of all publications indexed in the WoS (SCI-EXPANDED, SSCI, A&HCI). The total annual document counts of the studied OAMJs grew from 25,217 in 2012 to 50,732 in 2016 and except for *PLOS ONE, the rest* produced more articles in 2016 than in 2015. During the five years, the most significant increase in the number of publications can be seen in Nature's *Scientific Reports* which published 21,045 documents in 2016, almost 26-fold increase from 2012. In contrast, in the same period of time, *PLOS ONE*'s output declined from 23,456 in 2012 to 23,040 in 2016. Other OAMJs also grew during the period under investigation, but with much smaller numbers of publications. We can see a large variation in size among

OAMJs, in such a way that *PLOS ONE* and *Scientific Reports* publish thousands of documents per year, while other titles are still comparatively smaller in number. It should be noted here that since two OAMJs, *PeerJ* and *IEEE Access*, were launched in 2013, the output data for the overall publication does not represent a full five-year period.

Table 2: Annual Document Counts in the OAMJs Considered in This Study (2012-2016)

Journal	2012	2013	2014	2015	2016	Total
PLOS ONE	23456	31503	31482	29807	23040	139288
Scientific Reports	804	2554	4027	10948	21045	39378
BMJ Open	678	971	1131	1475	2074	6329
SpringerPlus	84	711	758	959	2115	4627
PeerJ	-	232	471	799	1298	2800
IEEE Access	-	63	126	249	819	1257
Biology Open	143	164	137	184	216	844
FEBS Open Bio	52	78	121	112	125	488
Total	25217	36276	38253	44533	50732	195011

Table 3 depicts different kinds of documents published in the OAMJs as labeled by WoS. Research articles were the most frequently published document type in OAMJs, accounted for nearly 96 percent of all publications, followed by erratums, reviews and meeting abstracts. The other document types, i.e. editorial material, letters and retraction reports altogether merely comprise less than 1 percent of the total. When some information is missing or unintentional mistakes occur in a published paper, the authors or the editors would write an erratum or correction to adjust and make the information reliable. The OAMJs selected in this study were found to have the correction publication rate of 2.66 percent. One may raise the question whether the existence of this considerable amount of errors occurred in OAMJ output resulted from the peer-review policy of these journals which evaluate only the scientific rigour of a work, and not to take into account its importance, novelty and impact.

Table 3: Document Types Published in the OAMJs Considered in This Study (2012-2016)

Mega Journal	Publications	Article	Review	Editorial Material	Retractions	Corrections	Meeting Abstracts	Letter
PLOS ONE	139288	133856	1290	33	62	4045	1	1
Scientific Reports	39378	38462	-	4	18	893	1	-
BMJ Open	6329	5632	499	1	-	197	-	-
SpringerPlus	4627	4246	226	4	-	30	116	5
PeerJ	2800	2779	21	-	-	-	-	-
IEEE Access	1257	1211	18	27	-	1	-	-
Biology Open	844	821	-	8	1	13	-	1
FEBS Open Bio	488	482	2	1	1	2	-	-
Overall	195011	187489	2056	78	82	5181	118	7

Figure 1 presents the share of publications in the OAMJs over the time period under investigation. The analysis of publication volumes showed that articles published by *Scientific Reports* rapidly grew from 3.19 percent in 2012 to 41.48 percent in 2016, while the share of *PLOS ONE* declined from 93.02 percent to 45.42 percent in the same time window.

It is clear from Figure 1 that *PLOS ONE* has started to lose OAMJ publishing market share, in particular to *Scientific Reports*. The share of other six OAMJs is also growing and they accounted for nearly 13 percent of the OAMJs market share in 2016.

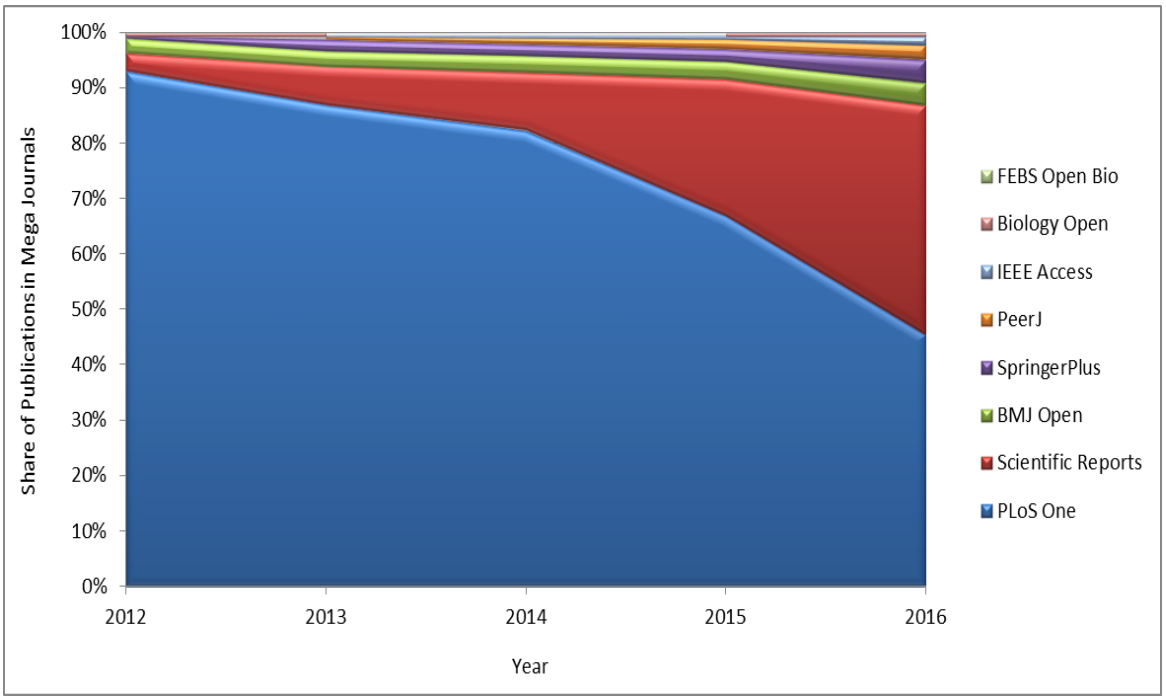

Figure 1: Share of Publications by Year in the OAMJs Considered in This Study

Bibliometric Performance of the OAMJs

Table 4 shows the bibliometric performance of the eight OAMJs. *PLOS ONE* and *Scientific Reports* had the highest paper counts, and subsequently garnered the largest number of citations. With regard to the mean citations per publication (CPP), *PLOS ONE* (11.05), *Scientific Reports* (10.32) and *IEEE Access* (9.24) recorded the topmost citation impact per publication within the analyzed time frame. As of September 2018, the point at which citation data was collected, over 90 percent of all papers published in *PLOS ONE*, *Scientific Reports, Biology Open* and *FEBS Open Bio* had been cited at least once. In contrast, *SpringerPlus* was clearly the worst performing OAMJ, with citedness rate (CR) of 69.11 percent. Among OAMJs under analysis, *IEEE Access* is clearly seen to have the highest share of highly-cited papers (HCP) (2.23%), while highly citedness rate in the other seven journals was below 1 percent e.g. 0.39 percent for *PLOS ONE* (i.e. having 540 papers in the top 1% most cited publication of the corresponding subject category in WoS) and 0.74 percent for *Scientific Reports*. In terms of the category normalized citation impact (CNCI) which is citations per publication normalized for journal, year and document type, *IEEE Access* (1.75) had a substantially higher value than the other OAMJs, while *FEBS Open Bio* (0.52) and *SpringerPlus* (0.40) showed extremely low values.

Consideration was also given to the JIF of studied OAMJs in 2017. As JIF is highly dependent on discipline-specific citation behavior and consequently not comparable among different fields of science, JIF percentile was selected to compare the relative significance and status of OAMJs in comparison with other journals in their respective subject category. *IEEE Access* was observed to have the highest JIF percentile (84.12 in the Computer Science, Information

Systems subject category; and 81.73 in the Engineering, Electrical & Electronics subject category), followed by *Scientific Reports* (82.03). The lowest JIF percentile was found to belong to *FEBS Open Bio* with JIF higher than just 21.4 percent of other journals in the Biochemistry, Molecular Biology subject category. As illustrated in the trend of JIF variation of the eight OAMJs in Figure 2, the most notable growth in JIF was observed in *IEEE Access* (from 1.27 in 2015 to 3.557 in 2017). Three OAMJs (*PLOS ONE, Scientific Reports* and *IEEE Explorer*) were ranked in the top quartile of their respective subject category in JCR; four journals (*BMJ Open, SpringerPlus, PeerJ* and *Biology Open*) in the second quartile; and one journal (*FEBS Open Bio*) in the bottom quartile.

Table 4: Bibliometric Performance of the OAMJs Considered in This Study

Mega Journal	Publications	Citations	CPP	CR (%)	No of HCP & (%)	CNCI	IF (2017)	IF Percentile (2017)	Quartile (2017)
PLOS ONE	139288	1539448	11.05	93.52	540 (0.39)	0.96	2.766	77.34	1
Scientific Reports	39378	406249	10.32	93.64	293 (0.74)	1.23	4.122	82.03	1
BMJ Open	6329	42755	6.75	89.10	19 (0.3)	0.84	2.413	72.40	2
SpringerPlus*	4627	12690	2.74	69.11	3 (0.06)	0.39	1.13*	53.9*	2*
PeerJ	2800	15322	5.47	88.55	14 (0.5)	0.40	2.118	71.09	2
IEEE Access	1257	11610	9.24	88.93	28 (2.23)	1.75	3.557	84.12	1
								81.73	1
								78.74	1
Biology Open	844	6288	7.45	92.89	1 (0.12)	0.97	2.217	68.82	2
FEBS Open Bio	488	3045	6.24	90.78	1 (0.2)	0.52	1.782	21.40	4

* SpringerPlus ceased publication in 2017 and consequently the 2017 IF was not calculated for this journal in the JCR. The IF shown belong to 2016.

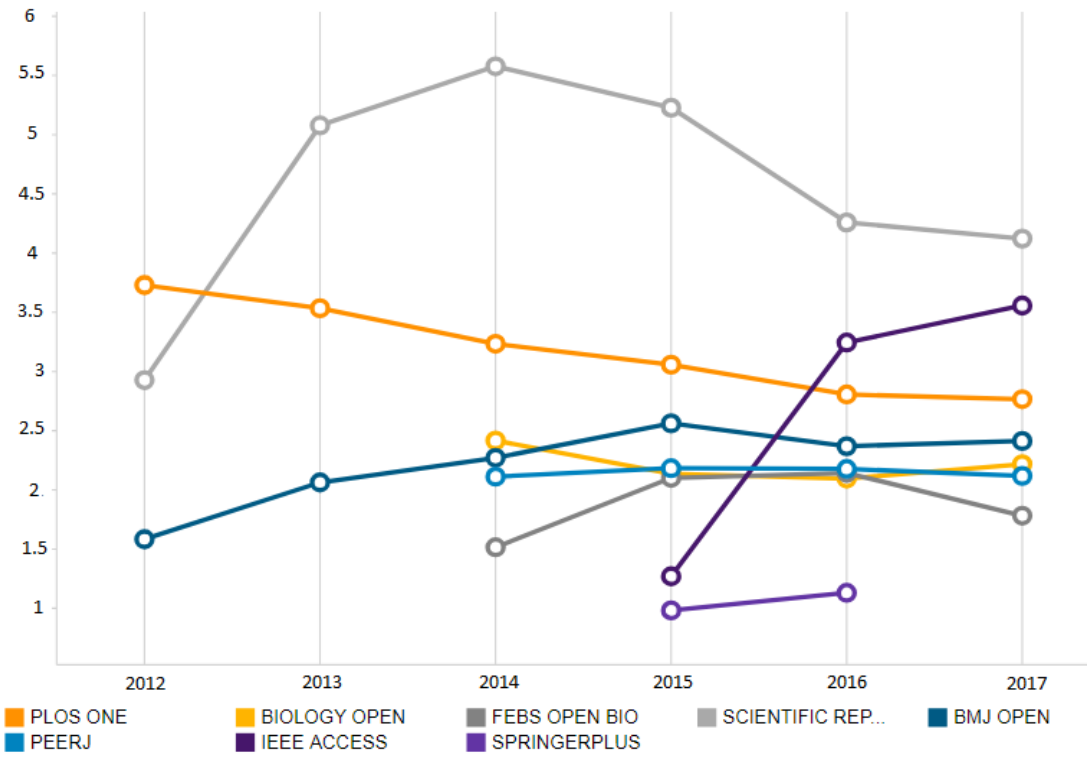

Figure 2: Trend of the Eight OAMJs' Journal Impact Factor During 2012-2016

Funding Agencies Supporting Articles Published in the OAMJs

OAMJ publishing system operates based on gold OA business model. Hence, OAMJs cover their production costs through pre-publication APCs from authors, funding agencies or authors' institutions. Ten major funding agencies, which are mainly government institutions, that had supported the publication of the eight OAMJs' output from 2012-2016 are shown in Figure 3. It shows that almost 26,000 papers (13.3% of all OAMJs' output) published in the eight selected OAMJs within the analyzed time frame were funded by the National Natural Science Foundation of China, followed by US National Institute of Health (10.9%), National Basic Research Program of China (3.1%) and US National Sciences Foundation (2.9%).

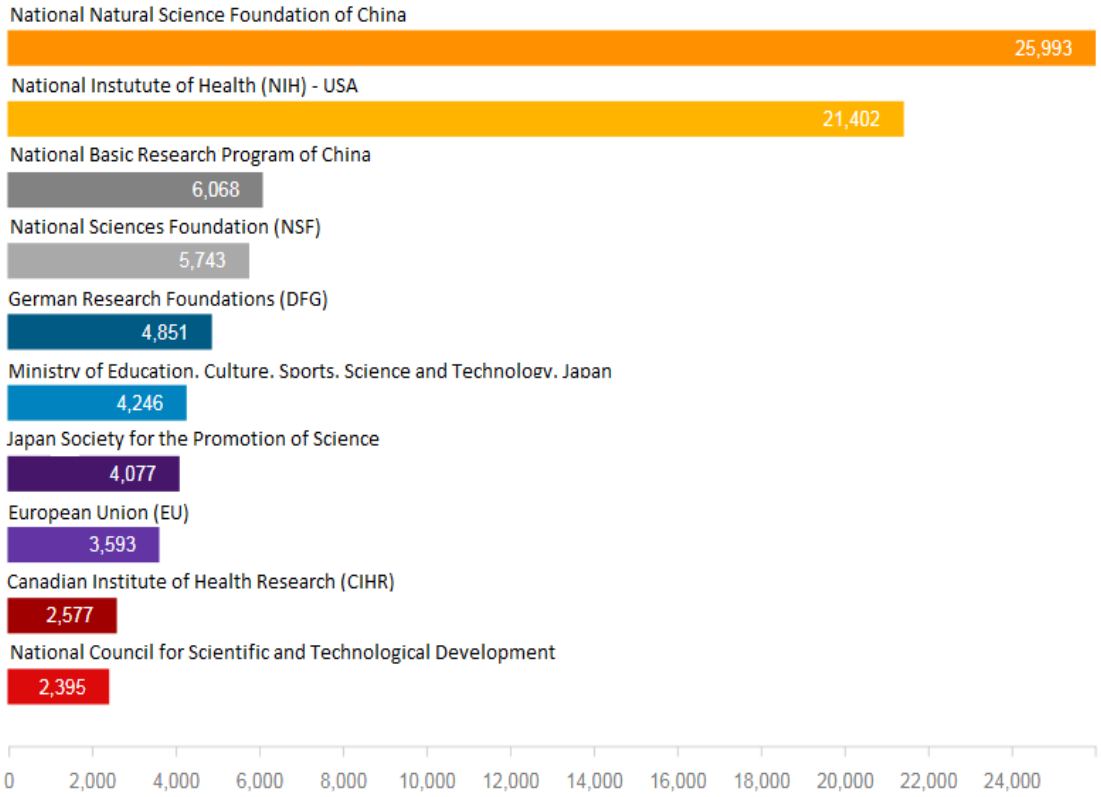

Figure 3: Ten Major Funding Agencies Supporting the Highest Number of Publications in the Eight OAMJs Considered in This Study

Disciplinary Scope of Articles Published in the OAMJs

Clarivate Analytics' InCites, which is a benchmarking and analytical tool, reclassified individual papers published in Multidisciplinary Science as well as General and Internal Medicine journals such as *Nature, Science, PLOS ONE* and *Scientific Reports* to their most relevant subject area. Top 10 subject categories of the articles published in the eight OAMJs during the period under investigation is presented in Figure 4. It is noticeable that a high proportion of articles published in the eight OAMJs are assigned to the Biochemistry & Molecular Biology subject area (12.48%), followed by Multidisciplinary Sciences (7.61%), Neurosciences (6.99%), Oncology (5.96%) and Immunology (4.11%). It is interesting to observe a clear dominance of biomedical and life sciences publications even in multidisciplinary OAMJs such as *PLOS ONE*, *Scientific Reports, SpringerPlus* and *PeerJ.*

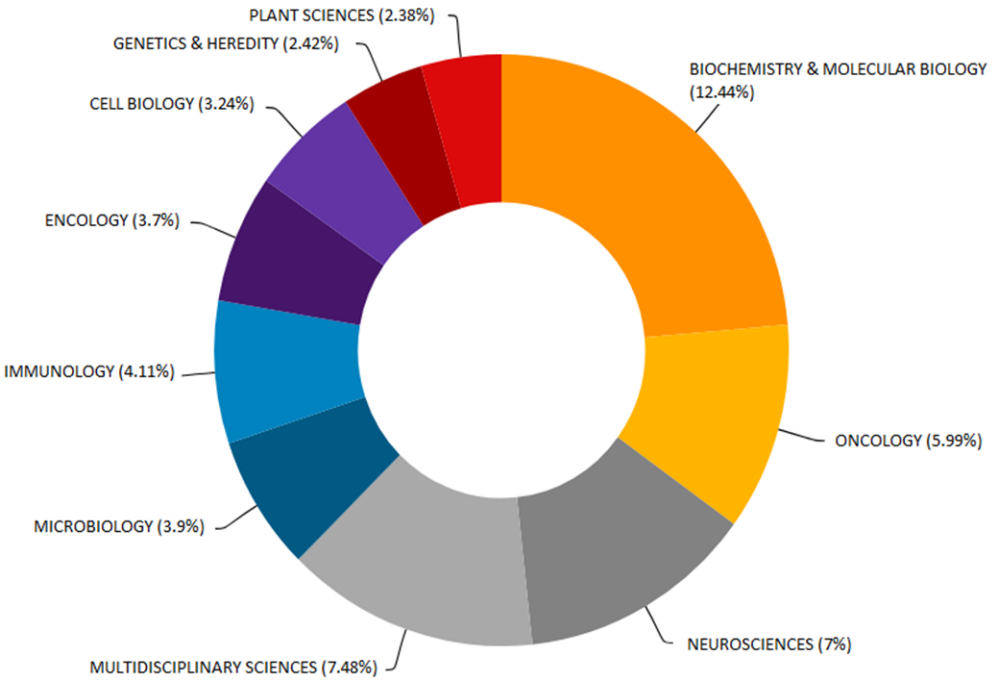

Figure 4: Most Frequent Subject Areas in Publications of the Eight OAMJs Considered in This Study (2012-2016)

Geographic Distribution of Articles Published in the OAMJs

There are 206 different author institutional affiliations represented in the eight selected OAMJs. The top 20 most productive countries of the publishing institutions publishing in these journals are presented in Table 5, along with the proportion of OAMJ outputs to their total publications in WoS. Results showed that the USA-based authors were the largest contributors to the eight OAMJs with 57,179 publications, followed by China (41,581), England (17,322), Germany (15,733) and Japan (13,104). In total, 98,757 documents (50.64%) were found to have at-least one author affiliated with institutions in the United States or China. It should also be noted that amongst the top 20 most productive countries, the highest proportion of publications in the eight OAMJs to the total publications in WoS belonged to Sweden (3.0%), followed by Denmark (2.71%) and Taiwan (2.66%).

The geographic distribution of the country's absolute publications in OAMJs is illustrated in Figure 5. In this heatmap, the color spectrum from blue to red indicates low to high volume of publications. If we consider the share of OAMJ output to the overall publications of each country, the graphical representation would be completely different. With regard to the share of publications in eight OAMJs, Guinea-Bissau tops the list with 12.87 percent of all publications of this country published in OAMJs, followed by the Gambia (11.9%), Central African Republic (10.09%) and Mozambique (9.87%) (Figure 6).

Table 5: Top Contributing Countries in the Eight OAMJs Considered in This Study (2012-2016) Ranked Based on Their Volume of Publications

Rank	Country	Number of Publications in 8 **OAMJs**	Total Publications in WoS	Share of Publications in 8 OAMJs
1	United States	57176	3252292	1.76
2	China	41581	1734874	2.40
3	England	17322	944282	1.83
4	Germany	15733	775934	2.03
5	Japan	13104	577593	2.27
6	France	10020	530095	1.89
7	Australia	10011	424923	2.36
8	Canada	9731	492787	1.97
9	Italy	7812	487938	1.60
10	Netherlands	7306	281661	2.59
11	Spain	7236	406713	1.78
12	South Korea	6327	353171	1.79
13	Sweden	5401	180050	3.00
14	Taiwan	4998	188192	2.66
15	India	4963	432951	1.15
16	Switzerland	4841	206085	2.35
17	Brazil	4794	273533	1.75
18	Denmark	3284	121042	2.71
19	Belgium	3272	155796	2.10
20	Scotland	2915	116351	2.51

Further analysis of country contribution revealed notable variations in the geographical distribution of authors in different OAMJs considered in this study. The United States was the country with the most contributing authors to three OAMJs – *PLOS ONE* (31.24%), *PeerJ* (37.88%) and *Biology Open* (33.53%). Likewise, a relatively high proportion of Chinese authors can be seen in three OAMJs – *IEEE Access* (37.58%), *Scientific Reports* (37.01%) and *SpringerPlus* (17.52%). Almost a third of the *BMJ Open* papers are affiliated to the institutions in England (32.5%), followed by the American and Australian-based authors with 16.94 percent and 12.78 percent of articles, respectively. Moreover, it is noticeable that *FEBS Open Bio* is the only OAMJ attracted more articles from Japanese authors (29.71%), than any other nationalities. Table 6 details the findings.

Table 6: Most Productive Countries in Each of the Eight OAMJ Considered in This Study

OAMJ	Most Productive Countries	OAMJ	Most Productive Countries
PLoS One	US (31.24%) China (17.87%) Germany (8.64%)	PeerJ	US (37.88%) England (12.59%) China (9.91%)
Scientific Reports	China (37.01%) US (26.18%) Japan (9.9%)	IEEE Access	China (37.58%) US (25.64%) England (11.94%)
BMJ Open	England (32.5%) US (16.94%) Australia (12.78%)	Biology Open	USA (33.53%) Japan (13.74%) England (12.68%)
SpringerPlus	China (17.52%) Japan (11.77%) US (11.75%)	FEBS Open Bio	Japan (29.71%) US (14.96%) China (13.93%)

Figure 5: Heatmap Illustrating Countries with the Highest Number of Publications in the Eight OAMJs Considered in This Study (2012-2016) (*the color spectrum from blue to red indicates low to high volume of publications*)

Figure 6: Heatmap Illustrating Countries with the Highest Proportion of Publications in the Eight OAMJs Considered in This Study (2012-2016) (*the color spectrum from blue to red indicates low to high proportion of publications*)

Mega-authorship Phenomenon in the OAMJs

Table 7 depicts the number of authors contributing to the published content of the eight selected OAMJs during 2012-2016. Findings showed that 81.2 percent of all publications in the OAMJs were produced by 1-9 author(s), while 17.8 percent and 0.8 percent of articles had 10-19 and 20-29 authors, respectively. As shown in Table 7, only 16 papers were authored by 100 or more contributors (13 in *PLOS ONE*; 3 in *Scientific Reports*). The highest number of co-authors belonged to a *PLOS ONE*'s paper published in 2015 with 195 contributing authors. It is also noteworthy that the most number of contributors in WoS comes from a paper published in *Physical Review Letters* in 2015, with 5124 authors.

Table 7: Distribution of Authors per Document in the Eight OAMJs During 2012-2016

Mega-Journal	1-9	10-19	20-29	30-39	40-49	50-99	100-999	> 1000
PLOS ONE	112751	25114	1135	174	52	49	13	-
Scientific Reports	30889	8059	350	58	7	12	3	-
BMJ Open	5239	997	74	14	2	3	-	-
SpringerPlus	4289	331	7	-	-	-	-	-
PeerJ	2662	134	2	2	-	-	-	-
IEEE Access	1243	14	-	-	-	-	-	-
Biology Open	756	87	1	-	-	-	-	-
FEBS Open Bio	438	48	2	-	-	-	-	-

DISCUSSION AND CONCLUSION

Today, OAMJs has been identified as a fast growing segment and an innovative publishing platform in the scholarly communication system. They have become substantial venues for disseminating scientific information in such a way that only eight OAMJs investigated in this research were responsible for 1.87 percent of the total number of publication indexed in WoS in the time period of 2012-2016. The current research is conducted with the aim of providing better insights into the increasingly important OAMJ phenomenon through investigation of eight reputable journal titles using established bibliometric methods. Results of the study revealed that several OAMJs started to appear on the market since 2011 as competitors for *PLOS ONE*. All eight titles were established by high-prestige publishers, especially those with commercial interests. The OAMJs charged authors a moderate amount of APC ranging from 1095 USD for *PeerJ* to 1770 USD for *BMJ Open*. In most of the cases, APCs of the OAMJs are considerably cheaper than that of reputable hybrid subscription-OA journals (Björk 2014). Despite the decline in publication count of *PLOS ONE* over the past couple of years, it was the largest journal in the world in terms of output until 2017, when *Scientific Reports* overtook *PLOS ONE* as the most productive journal. Other six OAMJs' output had an increasing trend over the time period under investigation, but with much smaller numbers of articles compared with *PLOS ONE* and *Scientific Reports.* A huge majority of papers published in the eight selected OAMJs were cited at least once at the point of analysis. The highest proportions of cited and un-cited documents were seen in *Scientific Reports* and *SpringerPlus*, respectively. With regard to the three indicators, namely share of highly-cited papers, the category normalized citation impact as well as the JIF percentile, *IEEE Access* had by far the best performance among the eight examined OAMJs.

Analysis of funding agencies supported OAMJ publishing revealed that the National Natural Science Foundation of China, the US National Institute of Health and the National Basic Research Program of China had the most significant contribution in providing research and publishing funds. Adopting a new approach of Clarivate Analyics' InCites in reclassification

of papers published in multidisciplinary and medical sciences journals, each paper was algorithmically reassigned to its most relevant subject area. Results revealed that Biochemistry & Molecular Biology, Multidisciplinary Sciences, Neurosciences, Oncology and Immunology were the most commonly assigned subject categories to OAMJs' content. This finding is consistent with that of Björk (2015), who found that the biomedical disciplines have dominated OAMJs publications. Investigation of the geographic distribution of authors showed that the United States and China by far had the highest contribution in the content of the eight studied OAMJs. There were, however, notable variations between different OAMJs. Chinese was the most common author nationality in three out of the eight studied OAMJs, namely *IEEE Access*, *Scientific Reports* and *SpringerPlus*. In line with this finding, Wakeling et al. (2016) reported a Chinese share of around 40 percent in *Scientific Reports, AIP Advances* and *Medicine.* The rising trend in the number of publications affiliated with Chinese authors can be explained by the fact that two of the three top funding agencies who supported publications of OAMJs financially were from China. Solomon (2014) reported that approximately half of the authors published in *PLOS ONE* were able to use grant funding. Other possible reasons for the rising share of Chinese authors in OAMJs discussed by Wakeling et al. (2016) and Björk (2018), include the high JIF quartile of some OAMJs such as *PLOS ONE* and *Scientific Reports*, moderate level of APCs, high visibility of the OAMJs, financial supports by the national and international funding agencies and not strict language requirements in OAMJs. It is notable that eleven out of the top 20 contributing countries were European-based, whereas five were Asian. The results showed that OAMJs attracted a considerable amount of articles even from developing and underdeveloped countries, in such a way that the highest proportion of OAMJs publications to the overall output of the country was seen in countries like Guinea-Bissau, Gambia and Central African Republic.

One interesting finding of this research was the notable amount of errata published in OAMJs. This can perhaps be at least partly explained by the 'publish first, judge later' policy which is embodied in OAMJ publishing system (Cope and Kalantzis 2014). The soundness-based quality assessment method operated by OAMJs has been criticized for not taking into account the perceived novelty of a piece of work, its potential significance to a field or its interest to scientific community (Spezi et al. 2017). Moreover, recruiting of a large number of editors, editorial board members and reviewers with a wide range of expertise would be a challenging responsibility of the OAMJ publishers which may negatively affect the quality filtering process (Wiser 2014). Further research is needed to study the probable reasons of errors occurred in the OAMJ outputs.

The continued success of OAMJs publishing system has motivated some questionable publishers to launch their illegitimate predatory OAMJ. They accept manuscripts without any transparent peer-review or quality control with the aim of charging APC from authors without providing any publishing services and editorial oversight (Erfanmanesh and Pourhossein 2017). Five predatory OAMJs were introduced by Beall (2013) and their content, user interface, pricing and contract options were discussed. To avoid being victimized by such questionable OAMJs, novice authors and early career researchers should be more familiar with scholarly publishing literacy skills to recognize and avoid publishing scams. Those coming from the developing countries especially are still in the early phase of the OAMJ publishing era and this phenomenon is rapidly moving into the mainstream of scholarly communication system.

The current research has attempted to capture an initial portrait of a selected number of OAMJs. The time span under analysis in this research was limited to five years and only eight OAMJs were selected for investigation. More extensive research can be done in future on

other OAMJs using different bibliometric indicators and altmetric approaches. Moreover, further research into the issues raised in this study would help in a deeper understanding of the OAMJ phenomenon.

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