Change and growth in open access journal publishing and charging trends 2011 – 2021

Principal Investigator & Corresponding author:

Heather Morrison
Heather.Morrison@uottawa.ca
School of Information Studies, University of Ottawa
111-08 Desmarais, 55 Laurier Avenue East
Ottawa, Ontario, Canada K1N 6N5

Authors

Heather Morrison, University of Ottawa
Heather.Morrison@uottawa.ca

Luan Borges, University of Ottawa
lborg090@uottawa.ca

Xuan Zhao, University of Ottawa
xzhao016@uottawa.ca

Tanoh Laurent Kakou, University of Ottawa
tkako061@uottawa.ca

Amit Nataraj Shanbhoug, University of Ottawa
ashan016@uottawa.ca

Biographical information about the authors and additional members of the *Sustaining the Knowledge Commons* team is available at https://sustainingknowledgecommons.org/about-the-team/

Abstract

This study examines trends in open access article processing charges (APCs) from 2011 – 2021, building on a 2011 study by Solomon & Björk (2012). Two methods are employed, a modified replica and a status update of the 2011 journals. Data is drawn from multiple sources and datasets are available as open data (Morrison et al, 2021). Most journals do not charge APCs; this has not changed. The global average *per-journal* APC increased slightly, from 906 USD to 958 USD, while the *per-article* average increased from 904 USD to 1,626 USD, indicating that authors choose to publish in more expensive journals. Publisher size, type, impact metrics and subject affect charging tendencies, average APC, and pricing trends. Half the journals from the 2011 sample are no longer listed in DOAJ in 2021, due to ceased publication or publisher de-listing. Conclusions include a caution about the potential of the APC model to increase costs beyond inflation. The university sector may be the most promising approach to economically sustainable no-fee OA journals. Universities publish many OA journals, nearly half of OA articles, tend not to charge APCs and when APCs are charged, the prices are very low on average.

Introduction

Open access (OA), the free online dissemination of scholarly works with little or no restrictions on downstream use, is broadly recognized as the optimal approach to dissemination. Major funding agencies now typically require OA to funded research. As of February 2022, the Registry of Open Access Repository Mandates and Policies (ROARMAP) (n.d.) lists over 1,100 OA policies in 5 continents. Since the Budapest Open Access Initiative (BOAI, 2002), two major approaches to achieving OA have been recognized, author self-archiving and OA publishing. Achieving sustainable OA scholarly publishing requires transition of underlying support from the demand (purchase / subscription) to the supply side (support for production). Crow (2009) identified nine supply side models for open access journals: article processing charges (APCs), advertising, sponsorships, internal subsidies, external subsidies, donations & fund-raising, endowments, in-kind support, and partnerships. This article focuses on one of these models, APCs, acknowledging that this model is used by a minority of OA journals. The Directory of Open Access Journals (DOAJ) current and historical metadata sets are central to this study. DOAJ is a vetted list of peer-reviewed scholarly journals that are fully OA, that is, all articles are OA immediately on publication, excluding hybrid journals with a mix of OA and subscription access content and journals that provide free access to back issues. During the time frame of this study, beginning in 2014, DOAJ initiated a "get-tough" policy, requiring listed journals to re-apply under a more rigorous vetting process. DOAJ adds journals continuously at a substantial rate, often averaging 3 or more journals per day. Of the 17,472 journals listed in DOAJ as of Feb. 17, 2022, 12,291 journals or 70% of the total are "without APCs". Bosman et al. (2021) recently completed a major study of 1,619 "diamond" (free for readers and authors) OA journals. Bosman et al. (2021, p. 8) describe this sector as economically reliant on volunteers, universities, and government. Crawford (2020, p. 20) found that most articles are published by universities and colleges.

The unique contribution of this study is a longitudinal comparison of APC trends through an update of a 2011 study of APCs by Solomon and Björk published in *JASIST* in 2012, using two methods: a modified replica of the 2011 study and an update of the 2011 dataset. The remainder of this section highlights only the most relevant works, all of which provide both context and data used in this study. There is a substantial body of literature on OA business models and a full literature review is beyond the scope of this article.

Solomon & Björk (2012) described APCs as a central funding mechanism for OA journals. They gathered APC data and 2010 article counts for 1,190 journals that were listed in DOAJ in 2011 and indicated use of APCs. They used weighting of journals from smaller publishers to estimate results for the full set of 1,370 APC charging DOAJ journals. Major findings include a global average APC of 906 USD calculated over journals and 904 to 1,626 USD calculated over articles, with a range of 8 – 3,900 USD. Lower pricing was associated with journals from developing countries, higher pricing with high impact factor journals from developed countries. Journals in biomedicine had the highest article counts and the highest APCs. Professional publishers had higher APCs than journals published by societies, universities, or researchers.

Morrison et al. (2019a, b) is an OA longitudinal survey of over 19,000 journals that includes the 2011 Solomon & Björk (2012) dataset, additional data from DOAJ on an annual basis from 2015 (including non-charging as well as APC journals) and publication fee data obtained from publisher websites for 2015 – 2019. Of the 19,000 journals, only journals found in the DOAJ 2021 dataset are included in this study. Morrison et al. emphasize that most OA journals do *not* charge APCs. While the global average APC in 2019 was found to be 908 USD, almost identical to the 2011 global average, the authors found that the average masked a more complex picture. For example, journals that were included in the 2011 sample were found to have increased in price by 50%, pricing trends on a per-journal basis suggested a mixed picture of prices increasing, decreasing, or remaining the same, and the "tendency to charge or not to charge, how much is charged and whether prices are increasing or decreasing varies considerably by journal, publisher, country of publication, language and currency".

Crawford (2020) reports on early 2020 APC (charging and non-charging) data of journals listed in DOAJ in 2020, a total of 13,948 journals, and 2019 article counts for these journals. Due to DOAJ journal additions and deletions from 2020 to 2021, not all journals in this dataset were matched in DOAJ 2021 and vice versa. Crawford reports that the global average APC was 1,023 USD "and probably less", and that while most journals do not charge APCs, most articles were published in APC-charging journals. Crawford breaks down pricing by publisher category, country of publisher, and subject. Crawford (2020, p. 20) found that most articles are published by universities and colleges. The OpenAPC (n.d.) group has automated collation of payment data for easy online data manipulation and visualization by APC payers on a per-article, per-journal, per-payer and per-year basis.

The use of metrics, particularly impact factor, in evaluation of research and researchers is widely criticized in scholarly communication, as a barrier to transition to open access, for example in the San Francisco *Declaration on Research Assessment* (2012) and the *Leiden Manifesto* (Hicks et al, 2014). Morrison (2021a) provides a broader critique of metrics-based evaluation of research and the conflation of the concept of impact with good quality. This study includes data from Journal Citation Reports (JCR), the relative impact factor, that is, a ranking of journals based on average citations to articles in that journal, as well as Scopus citations data.

Research questions

This study draws on two distinct but interrelated research methods. For this reason, each research question indicates whether the results reflect Method 1 or Method 2. The Methods are explained in the next section.

1. How does DOAJ in 2020 compare with 2011 in terms of number of journals overall, number of APC charging journals and central tendencies of APC pricing? (Method 1).

2. Is APC pricing of journals listed in DOAJ in 2020 (amount and tendency to charge or not charge) associated with publisher sizes, publisher types, relative impact factor ranking, and/or subjects, and how does this compare with 2011? (Method 1).
3. What is the current status of the 1,090 APC-charging journals included in Solomon and Björk (2012) (active v. ceased, current listing in DOAJ, OA status, per-journal price changes)? (Method 2)
4. What are the pricing trends for the 1,090 APC-charging journals included in Solomon and Björk (2012) that are still active, OA, and charging APCs? How do the pricing trends for these established journals compare with the global DOAJ 2020, and what does this suggest about the sustainability of the APC method? (Method 2)

Method

Method 1. 2021 modified replica of 2012 Solomon and Björk study

Solomon & Björk (2012) conducted a weighted sampling limited to APC charging journals listed in DOAJ as of 2011 (1,090 of 1,370 APC journals). The "replica" study departs from the original in several important respects. This replica is a full sample of both charging and non-charging journals in DOAJ as of 2021 (15,690 journals), and a full rather than weighted sampling of APC charging journals in DOAJ (4,368 journals), made possible by merging data from multiple sources. The list of titles is substantially different due to the 2014 DOAJ "get-tough" policy and the continuous substantial addition of new titles. Other modifications reflect new approaches to impact factor and subject analysis. Impact factor division into upper and lower half based on CiteScore (Scopus) is the same. Impact factor based on JCR is simply divided into the upper and lower half of the journals included rather than median of the JCR Science and Social Science Reports approach of 2010. The difference in subject analysis reflects change in the DOAJ metadata. The subject analysis results are roughly comparable at broad ranges such as STM versus humanities, but not directly comparable for individual subjects.

DOAJ metadata (15,690 journals) was downloaded on Jan. 5, 2021. Zhao, Borges & Morrison (2021) document preparatory clean-up and standardization of the DOAJ metadata. Additional data was merged from the open datasets of Morrison et al. (2019b), Crawford (2020), Solomon & Björk (2012), JCR (2019) and Scopus (2020). The resulting dataset (DOAJ 2021+) has been published as open data (Morrison et al., 2021b), with proprietary JCR and Scopus data removed. An August 29, 2011 DOAJ metadata set collected by the authors for a different study was used to compare overall DOAJ numbers and APC charging status from 2011 – 2021.

Current APC status (charging and non-charging) and amount was determined using data from DOAJ (2021) for 6,911 journals, 44% of the 15,690 journals in total. Of these journals, DOAJ data was selected for use based on whether the data was reasonably up to date. 3,548 of the journals were added in DOAJ as of 2019 or later, and 3,363 journals were last updated in DOAJ as of 2019 or later. This left 8,779 journals or 66% of the total for which DOAJ data dated from 2018 or earlier. To obtain a more current sample, APC status and amount was merged from Crawford (2020) for 6,128 journals (39% of the total) (data gathered from publisher websites early 2020) and Morrison et al. (2019) for 2,626 journals (17% of the total) (data gathered from publisher websites in 2019). There were 25 titles for which DOAJ data dated 2018 or earlier was the only information available. It is estimated that APC status and amount dates from 2019 – early Jan. 2021 for about 95 – 99% of the 15,690 journals. The lack of precision reflects uncertainty about whether a DOAJ "last update" date reflects updating of APC status and

amount or is limited to other updates such as corrections of URLs, journal or publisher name changes or corrections.

Pricing analysis, including calculation of central tendencies and price bands by journal and by article, follows the method used by Solomon and Björk (2012) except for expansion from a weighted to a full sample. Solomon and Björk's per-journal and per-article price analysis is based on a weighted sample of 1,090 of 1,370 APC journals listed in DOAJ in 2011. Our per-journal price analysis reflects a full sample of the 4,368 journals for which we were able to identify a specific APC amount of 2019 or later; our per-article analysis is limited to 3,662 journals for which 2019 article counts are available from Crawford's (2020) sample. The per-article analysis, based on Crawford's data, does not include journals with no articles published in 2019 or journals added to DOAJ in 2020 or 2021. Figures follow the same pattern used by Solomon and Björk (2012) to facilitate comparison. The comparison of 2011 and 2019 articles by price band incorporates re-analysis of 2011 data as provided by Solomon and Björk (2012). Article counts are for 2010 Solomon and Björk (2012) and 2019 (Crawford, 2020), while APC pricing is for 2011 and 2019 – 2021. Currency conversion to USD was based on the XE currency conversion service data for Jan. 5, 2021.

Publisher size and type are both based on DOAJ metadata and are challenging to assess for several reasons. Professional publishers, whether not-for-profits like Ubiquity Press and Public Library of Science or commercial publishers such as Elsevier or SpringerNature, are relatively easy to identify. However, assessing the full size of a publisher requires identifying and collating imprints. SpringerNature includes Springer Open, BioMedCentral, and Nature. Sciendo is owned by DeGruyter. Hindawi was recently purchased by Wiley. Many journals do not necessarily *have* a publisher. DOAJ "publisher names" are sometimes the journal title or the name of an editor. Variations in publisher names are common, and typos are common, as explained in Zhao, Borges & Morrison (2021). To assess publisher size, a new column was created to list standardized publisher names to the extent that we were able to identify these.

Publisher type was determined based on a combination of publisher name in DOAJ (e.g. known publishers, variations of "university" or "society") and DOAJ "society or institution" metadata. Journals that listed the journal name or member of the editorial board as the publisher were considered independent. University and university press publishers are distinguished by language indicating a formal press. For example, when the publisher in DOAJ is listed as University of Cambridge, it is considered a university publisher, but when the listing is Cambridge University Press, it is considered a university press.

To minimize complexity, the DOAJ 2021 + dataset is referred as DOAJ 2021+ although the actual data is from 2019 – 2021 and citation data (JCR and Scopus) reflects earlier citations.

Method 2. 2011 dataset update: current status and trends

The 2011 data on which the Solomon and Björk (2012) article was based forms the base for this study. Data on current status, (e.g., whether the journal is still active, open access, and APC charges, and the amount in the original currency) was obtained from the DOAJ 2021+ dataset created for the modified replication study described above, with additional data from Morrison et al. (2019), publisher websites, CLOCKSS, and web searches for journals and publishers. CLOCKSS https://clockss.org/ is a collaboration of the world's leading academic publishers and research libraries to create a sustainable dark archive. OA journals in the archive are not available to the public unless a "trigger" event occurs, such as when a

journal discontinues publishing. CLOCKSS data was used to verify status of journals no longer available at the original website. JCR 2010 data (not included in the original provided by Solomon and Björk) was added for the impact factor analysis. The dataset 2011 – 2021 APCs has been published as open data (Morrison et al, 2021b).

Inflation rates are based on the website U.S. Inflation Rate Calculator (n.d.) as of April 2021, which indicates an inflation rate of 20.5% in the time frame 2011 – 2021 (average 1.9% / year), and the EU Eurostat, indicating and inflation rate of 14.6% from 2011 – 2021 (average 1.4% / year).

Results

Modified replication of the Solomon and Björk 2011 study

Overall growth and charging trends in open access journals 2011 – 2021

As is evident in the section title, there were more open access journals in 2021 than in 2011 – but what is the volume of growth, and is the tendency the same for charging and non-charging journals? The following Table 1 *DOAJ Journals and APC charging status comparison 2011 – 2021* shows changes in the number of journals listed in DOAJ overall and by APC charging status. In August 2011, 6,946 journals were listed in DOAJ; of these, 68% did not charge APCs. In January 2021, 15,690 journals were listed in DOAJ; 73% did not charge APCs, 70% when factoring in other data sources, Morrison et al. (2019) and Crawford (2020). This illustrates that DOAJ net growth (journals added – journals deleted) reflects more than doubling in a decade. DOAJ metadata on charging status has changed to a straightforward no / yes; in 2011 there was a "conditional" option. The number of journals with "Yes" to charging status in 2021 includes 4,368 journals for which a specific amount was identified and 159 journals for which a specific amount was not identified (80 journals using per-page rather than per-article charges, 58 new journals indicating an APC model but not yet charging, 19 journals indicating charges without specifying an amount, 1 journal charging "by publishing unit", and 1 journal that negotiates fees with conference organizers). Table 1 below illustrates that DOAJ growth reflects the same proportion of APC charging and non-charging journals in 2011 and 2021.

DOAJ Journals and APC charging status comparison 2011 - 2021						
	DOAJ metadata 2011		DOAJ metadata 2021		DOAJ 2021 + other sources	
APC charging status	# Journals	% Journals[1]	# Journals	% Journals	# Journals	% Journals[1]
No	4,745	68%	11,399	73%	11,050	70%
Yes	1,840	26%	4,291	27%	4,527	29%
Information missing	236	3%			70	0.4%
Conditional	112	2%				
Blank (2011) / Other (2021)	13	0.2%			43	0.3%
Total DOAJ journals	6,946		15,690		15,690	
[1] *percentages do not add up to 100% due to rounding error*						

Table 1. DOAJ Journals and APC charging status comparison 2011 - 2021

The 4,368 journals for which a specific APC amount dating from 2019 – 2021 could be identified are included in the APC analysis. Per-article analysis is based on a subset of 3,662 of these journals for which a 2019 article count by Crawford (2020) was available. The average APC of this subset of journals was obtained by multiplying the journal APC by the number of articles published, adding the per-journal totals, and dividing by the total number of articles. The median was obtained by sorting the spreadsheet according to the APC and using an iterative approach of adding the number of articles published in all the journals to find the point where half the articles were published in less expensive journals and half in more expensive journals. Table 2 *Article processing charges in U.S. dollars 2019 – 2020 with summary statistics presented by journals and articles* lists the central tendencies including range, average (mean), median and mode by journal and article. The range of APCs was <1 – 5,200 USD (a few journals have APCs of less than 1 USD after currency conversion). The per-journal average APC is 958 USD while the per-article average APC is 1,626, suggesting that authors are more likely to choose to publish in more expensive journals. Table 2 illustrates the central tendencies in USD for the 501,950 articles published in APC journals. This is 5 times the 100,697 articles reported by Solomon and Björk (2012), indicating substantial growth in the APC market, and is an underestimate as article counts are available for only 3,662 of the 4,368 journals.

Article processing charges in U.S. dollars 2019 – 2020 with summary statistics presented by journals and articles		
	By journal	By article published in 2019
	Includes both journals **with and without** a 2019 article count	Includes **only** journals with a 2019 article count [1]
Average (Mean)	958	1,626
Median	650	1,757[2]
Standard Deviation	955	946
Minimum	<1[3]	<1[3]
Maximum	5,200	5,200
Count	4,368 journals	501,950 articles

[1]Total number of APC journals for which we have a 2019 article count is 3,662 journals.
[2]This is the median APC by articles published, that is, half the articles were published in a journal with a lower APC and half were published in a journal with a higher APC.
[3]These are journals from developing countries with very low fees that translate into less than one USD.

Table 2. - *Article processing charges in U.S. dollars 2019 – 2020 with summary statistics presented by* journals and articles

The average (mean) price can be useful – or deceptive. For example, the global average (mean) APC tends to be skewed by large numbers of journals published in the developing world whose prices appear to be extremely low when translated into USD. This is illustrated in Table 3 *Journals by price band 2021* below. Nearly half the journals have an APC of 500 USD or less. This is less than a quarter of the per-article average in Table. 2.

Journals by price band 2021	
APC in USD	# Journals
0 - 500	2,037
501 - 1,000	607
1,001 - 1,500	476

1,501 - 2,000	548
2,001 - 2,500	436
2,501 - 3,000	145
3,001 - 3,500	83
3,501 - 4,000	19
4,001 - 4,500	4
4,501 - 5,000	1
5,001 - 5,200	12
Total	4,368

Table 3 Journals by price band 2021

Price band analysis can help to elucidate the trends. Figure 1 below *% of articles by APC price band in USD 2010 and 2019* draws on Solomon & Björk's (2012) 2011 data including a 2010 article count for 2010 data and the 3,662 journals for which we have a specific APC amount and a 2019 article count from Crawford (2020). The upper end of the 2020 APC price bands is more than a thousand dollars higher than in 2011. 2010 article percentages peak at 1,801 – 2,000 USD. 2019 article percentages peak at 2,001 – 2,200. The percentage of articles at APC price bands above the peak is higher in 2019 than in 2010. This suggests a trend of price increases. The % of 2010 articles at the very lowest price band is likely understated due to Solomon & Björk's weighting of smaller journal publishers; the trend towards lower prices for smaller publishers is evident in 2019 as presented below in the section on publisher size.

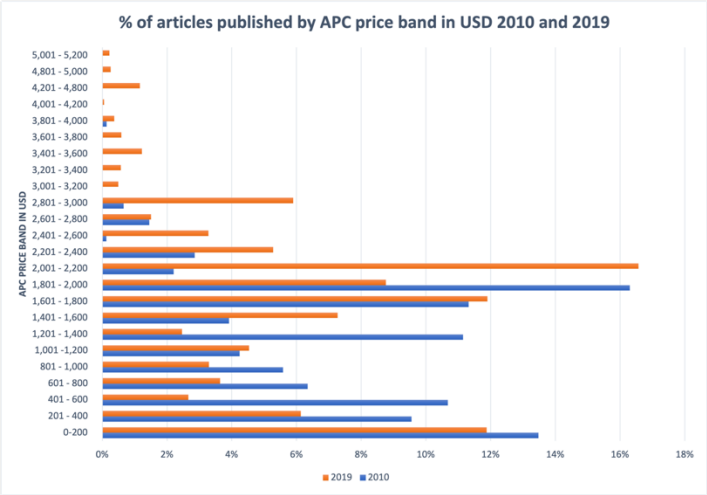

Figure 1 *% of articles by APC price band in USD 2010 and 2019*

Journals and APC by publisher size

Does the APC correlate with publisher size? This might make sense. A scholarly society that publishes a single journal may have smaller costs than a professional or commercial publisher with many journals (for example, reliance on in-kind support from universities in contrast with paying for office space and computing equipment). The following Table 4 *DOAJ 2021: journals and average APC (USD) by publisher size* illustrates a long tail effect. Most publishers are small, and most journals are published by small

publishers. Of the 6,804 publishers identified, 5,305 or 78% publish only one journal. 6,640 or 98% publish 10 journals or less. About one third of journals (34%) are published by very small publishers with only 1 journal, two thirds (34 + 29 = 63%) by publishers with 2 – 10 journals and 85% by publishers with 25 journals or fewer. Of the publishers with more than one journal, many publish both no-fee and APC journals. The average APC is noticeably lower for journals by small publishers (<400 USD for 1 – 10 journals) and higher for larger publishers (> 1,000 USD for 26 or more journals), with publishers of 11 – 25 journals in between at about 800 USD.

DOAJ 2021: journals and average APC (USD) by publisher size								
Publisher size by # of journals	# Publishers	# Journals	# No-fee journals	# APC journals	# Other journals	Average APC in USD	% Of no-fee journals[1]	% Of all journals
1	5,305	5,305	4,358	926	21	306	39%	34%
2- 10	1,335	4,550	3,617	908	25	396	33%	29%
11 -25	114	1,823	1,441	376	6	799	13%	12%
26 - 50	33	1,136	761	364	11	1,116	7%	7%
51 - 100	7	523	210	309	4	1,644	2%	3%
101 - 200	3	479	39	437	3	1,640	0.4%	3%
200 +	7	1,874	624	1,207	43	1,456	6%	12%
Total	6,804	15,690	11,050	4,527	113			
[1] *Percentages do not add up to 100% due to rounding error*								

Table 4. *DOAJ 2021: journals and average APC (USD) by publisher size*

Relative publisher size varies by journal and by articles. Elsevier is the largest publisher in this dataset by number of journals (386), while MDPI is the largest publisher by number of articles published in 2019 (104,948). A few publishers rank highly by number of articles published with a low journal count, reflecting publication of journals that publish many articles (both traditional and OA mega-journals). For example, Public Library of Science (PLoS), publisher of the pioneer OA megajournal PLoS ONE, ranks 6th by number of articles (19,632 articles), with only 7 journals, while IEEE, a traditional society publisher in engineering, a field where journals that publish articles in the thousands per year is common, ranks 9th with 16,233 articles in only 5 journals. Although as shown by Table 4. *DOAJ 2021: journals and average APC (USD) by publisher size* above, larger publishers *tend* to publish journals with higher average APCs, the publishers with the highest APCs are not necessarily the largest publishers by either journal or article. Elsevier, the largest publisher by number of journals and second largest by number of articles, ranks 50th by average APC. The National Institutes of Health Research (NIHR) Journals library has the highest average APC of 4,086 USD with only 5 journals and 154 articles. 8 of the most expensive publishers are in the biosciences. Full data is available in the open datasets *Publisher size by # journals*, *Publisher size by # articles*, and *Publisher by average APC* (the 3 datasets include the same data, organized for reader convenience).

Publisher type

A related question is whether publisher type impacts charging trends; are scholar-led journals less likely to charge, or less costly, than professional or commercial publishers? Table 5 *Publisher type analysis*

illustrates the size of publishers by type by the number of journals, number of articles published in 2019, broken down by no-fee and APC journals, and the average APC in USD. Universities stand out as having published the largest number of journals, 9,330 or 63% of the 14,764 with an identified publisher type, an even higher percentage of the no-fee journals, 7,857 or 75% of the 10,463 no-fee journals, the second highest number of articles published in 2019, and a low average APC of 234 USD, a quarter of the overall average. The commercial sector published the largest portion of articles, 312,770 or 39% of the 810,358 articles, and was the only publisher type that published more APC than no-fee journals, 275 or 18% of the commercial sector journals were no-fee, likely due to sponsor-partners such as societies and universities. The society or institution type had the highest average APC in USD at 1,606. The commercial, society, non-profit, and university press types all had above-average APCs. Some publisher types had low numbers of journals (government and institute); hence caution is recommended in interpreting the results.

Publisher type analysis					
Publisher type	# Journals	# Articles 2019	No fee journals (%)	APC journals (%)	Average APC by Journal (USD)
Commercial	1,850	312,770	15	85	1,511
Government	55	2,779	91	9	657
Independent	206	7,243	90	10	194
Institute	72	358	85	15	132
Non-profit	79	22,923	52	48	1,038
Society	2,246	144,865	63	37	1,180
Society or Institution	440	24,483	50	50	1,606
University	9,330	275,709	84	16	234
University Press	486	19,228	74	26	1,370
Total	14,764	810,358	71	29	986

Table 5. Publisher type analysis

Average APC in USD by impact factor category

Do charging trends correlate with impact factor? Yes, they do. Table 6 *DOAJ 2021 yes / no status, Scopus & JCR below* shows the number of journals and APC status listed in DOAJ according to whether the journals are indexed in JCR, Scopus, or neither. Many journals are indexed in both JCR and Scopus. 70% of the 15,690 journals listed in DOAJ 2021 are not listed in either JCR or Scopus. 10% of DOAJ journals are listed in JCR. 28% of DOAJ journals are listed in Scopus. This analysis illustrates a higher tendency for journals listed in JCR or Scopus to charge APCs; 72% of journals listed in JCR charge APCs and 45% of journals listed in Scopus, compared to 19% of journals not listed in either JCR or Scopus.

DOAJ 2021 yes / no status, Scopus & JCR						
Not indexed in JCR or Scopus			JCR Journals		Scopus Journals	
APC?	# Journals	% Journals	# Journals	% Journals	# Journals	% Journals
No	8,947	81%	461	28%	2,411	55%

Yes	2,122	19%	1,170	72%	1,996	45%
Total	11,069	100%	1,631	100%	4,407	100%

Table 6 DOAJ 2021 yes / no status, Scopus & JCR

Does the impact of a journal correlate with price? Yes – higher impact correlates with higher price. The Table 7 *Average APC in USD by impact factor* below was developed by dividing journals in half based on impact status as measured by JCR rank or Scopus CiteScore (a count of citations). Average APC was calculated for the subset of journals for which a specific APC amount was identified. The per-article amount was determined by multiplying APC by article count from Crawford (2020), where available, and dividing the total by the number of articles. Table 7 demonstrates much higher APCs for journals listed in either JCR or Scopus and higher APCs for high vs. low impact journals, by journal and by article. For APC journals not listed in either Scopus or JCR, the per-journal average is 561 USD compared to 2,709 USD for high impact journals listed in JCR by article.

Average APC in USD by impact factor					
	Not indexed in Scopus or JCR	Scopus low impact	Scopus high impact	JCR low impact	JCR high impact
By journal	561	916	1,685	1,231	2,133
By article	649	1,054	1,658	1,803	2,709

Table 7 Average APC in USD by impact factor

Figure 2 *Average APC in USD by impact factor* below illustrates the same data.

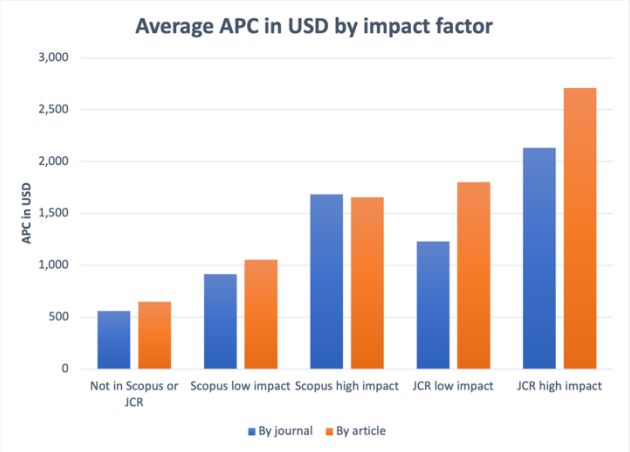

Figure 2 Average APC in USD by impact factor

APC status and average by subject

DOAJ subject metadata has changed considerably since 2011. For this reason, this portion of the replica study is less comparable with the 2011 study than other results. The subject in Table 8 Subject Analysis below was determined by the main subject heading in DOAJ. For example, specific branches of medicine are included in the subject "Medicine". The APC journals used for this analysis are the 4,368 journals for

which we were able to identify an APC of a specific amount. Per-article APC is derived from the 3,662 journals for which we have both an APC and a 2019 article count. All subjects have more no-fee than APC journals, while the percentage of no-fee and fee varies considerably. In Language and Literature there are 1,006 no-fee journals and only 78 APC journals. The average APC by journal or by article varies considerably by subject. For example, Education, History, and Social Sciences' average APCs by journal are a fraction of the overall average, while Medicine and Science are above the average.

Subject analysis						
DOAJ Primary Subject	# Journals	# Articles published in 2019	# No fee journals	# APC journals	Average APC in USD (journal)	Average APC in USD (article)
Agriculture	738	33,319	397	337	519	851
Auxiliary sciences of history	103	1,952	91	12	532	506
Bibliography. Library science. Information resources	150	3,309	143	7	264	297
Education	1,505	41,512	1,205	292	235	376
Fine Arts	434	9,817	394	37	508	457
General Works	295	10,406	260	33	408	413
Geography. Anthropology. Recreation	817	28,128	636	178	831	1,163
History	432	9,672	416	15	164	377
Language and Literature	1,093	24,691	1,006	78	192	290
Law	540	10,464	485	47	406	530
Medicine	3,347	291,940	1,698	1,626	1,373	1,753
Military Science	33	935	29	3	22	24
Music	48	731	43	5	453	218
Naval Science	21	1,247	15	5	329	449
Philosophy. Psychology. Religion	798	21,920	684	109	402	1,634
Political science	376	8,268	334	37	293	370
Science	1,519	148,106	797	710	1,122	1,967
Social Sciences	1,686	43,413	1,355	321	365	419
Technology	1,755	144,605	1,062	675	977	1,591
Total	15,690	834,435	11,050	4,527	958	1,662

Table 8. Subject analysis

Current status and trends of 1,090 journals studied by Solomon & Björk (2012) in 2011

Most of these journals (755 or 69%) are still active, open access, and fee-charging. 274 journals (25%) have ceased publication. 11 journals are active and open access but no longer fee-charging. One publisher (Kamla-Raj) is now subscription-based, and 2 journals are now hybrid (some articles open access, others by subscription only). The following Table 9 *2021 status of 2011 OA APC journals* details the current status of all 1,090 journals.

2021 status of 2011 OA APC journals		
Status	# Journals	% Journals
Active, OA, fee	755	69%
Active, OA, no fee	11	1%
Ceased publication	274	25%
Hybrid	2	0%
Inactive	3	0%
Predecessor	4	0%
Subscription journal / publisher	9	1%
Title not found	32	3%
Total	1,090	

Table 9 *2021 status of 2011 OA APC journals*

More than half the APC journals studied by Solomon & Björk are no longer listed in DOAJ as of 2021, as illustrated in the Table 10 *DOAJ inclusion status of 2011 APC journals*.

DOAJ inclusion status of 2011 APC journals		
Listed in DOAJ 2021?	# Journals	% Journals
No	578	53%
Yes	512	47%
Total	1,090	

Table 10 DOAJ inclusion status of 2011 APC journals

Of the 578 journals no longer listed in DOAJ, 254 are still active, open access and fee charging. Of these, 251 are published by publishers that are no longer represented in DOAJ; these are listed in the *Publishers No Longer in DOAJ* appendix.

Results of the replica study above illustrate that the average APC of journals listed in DOAJ in 2011 has increased. However, the set of journals listed in DOAJ is not the same in 2021 as it was in 2011; half the 2011 journals are no longer listed, and DOAJ is much larger in 2021, so that most of the 2021 journals were not included in the 2011 dataset. How does the pricing compare for those journals for which data is available in both years? Table 11 *2011 and 2021 APC comparison: 718 journals for which 2011 and 2021 APC data is available* shows the central tendencies for both years and the breakdown by DOAJ journal inclusion / exclusion in 2021. The average APC of this set of journals increased from 1,109 USD to

1,459 USD, a 32% increase that is well beyond the inflation rate in this time frame of 20.5% in the U.S. and 14.6% in the EU. DOAJ inclusion / exclusion showed different patterns. The average APC of journals included in DOAJ in 2021 show a much higher increase to an average of 1,800 USD, a 62% increase, while journals not listed in DOAJ in 2021 showed an average price *decrease* to 772 USD, a 30% decrease.

2011 and 2021 APC comparison: 718 journals for which 2011 and 2021 APC data is available				
2021 APC (USD)	2011 APC (USD)	2021 APC (USD) All journals	2021 APC (USD) Journals listed in DOAJ 2021	2021 APC (USD) Journals not listed in DOAJ 2021
Average (Mean)	1,109	1,459	1,800	772
Median	1,000	1,588	1,958	599
Mode	1,610	1,958	1,958	960
Lowest	13	1	45	1
Highest	3,900	4,200	4,200	4,171

Table 11. *2011 and 2021 APC comparison: 718 journals for which 2011 and 2021 APC data is available*

The status and APC of 176 journals included in the 2011 dataset of 1,090 journals that are also listed in the 2010 JCR is displayed in Table 12 *2021 status of 2011 OA APC journals listed in JCR 2010*. APC was calculated for all the JCR journals, and separately by the top and bottom half of the JCR journals by JCR rank, as illustrated in the Table 12 *2021 status of 2011 OA APC journals listed in JCR 2010*. In contrast with the full dataset, almost all the JCR journals are active, OA, fee charging (99%), and listed in DOAJ in 2021, with one exception due to a title change (Predecessor).

2021 status of 2011 OA APC journals listed in JCR 2010		
Status	# Journals	% Journals
Active, OA, fee	174	99%
Active, OA, no fee	1	1%
Predecessor (not listed in DOAJ 2021)	1	1%
Total	176	100%

Table 12 2021 status of 2011 OA APC journals listed in JCR 2010

Not surprisingly, higher ranked journals have a higher mean (average) and median APC as illustrated by the Table 13 *2021 APC in USD of OA APC journals listed in JCR 2010*.

2021 APC in USD of OA APC journals listed in JCR 2010			
	All journals	Top half by rank	Bottom half by rank
Mean	2,032	2,301	1,776
Median	2,135	2,247	2,029
Mode	2,302	1,866	2,302
Lowest	62	1,075	62

Highest	4,200	4,200	3,119

Table 13 2021 APC in USD of OA APC journals listed in JCR 201

Discussion

Change and growth in open access journal publishing and charging trends 2011 – 2021

DOAJ's net growth from 2011 – 2021 more than doubled and the percentage of charging and non-charging journals is steady, with most journals (68%) not charging and about 26% charging APCs.

This robust growth is in spite of the fact that over half the 1,090 APC-charging DOAJ journals studied by Solomon & Björk (2012) in 2011 are not listed in DOAJ 2021. This is likely due to several factors. Some journals have ceased publication. Some of the pioneering commercial OA journal publishers (BioMedCentral, Hindawi, Bentham Open) began with a very large number of journals covering many disciplines, then retired journals that were less successful in attracting content. Another factor is the 2014 DOAJ "get-tough" policy. Of the journals and publishers that were de-listed from DOAJ, there is one that would fit the label "predatory". The publisher OMICS, included in DOAJ in 2011 but not 2021, was order by a U.S. federal district court to pay $50.1 million USD "to resolve FTC charges that they made deceptive claims about the nature of their conferences and publications, and hid steep publication fees" (U.S. Federation Trade Commission, 2019). Although OMICS is no longer included in DOAJ, the company is still actively publishing. There are reasons for exclusion from DOAJ that have nothing to do with "predatory" practices. Journals that mix OA and subscription content are not eligible. It is possible that some journals or publishers simply did not complete the re-application process.

APC pricing trends 2011 – 2021

The global average per-journal APC has increased at a rate below inflation, from 906 to 958 USD, a 6% increase in contrast to the inflation rate in this time frame of 20.5% in the U.S. and 14.6% in the EU. Other indicators, such as the average per-article APC and the average APC of journals included in the 2011 sample, indicate price rises far beyond inflation. The average per-article APC rose from 904 to 1,626, an 80% increase or approximately quadruple the US inflation rate. The average 2021 APC of the journals listed in DOAJ in 2011 rose from 904 to 1,459, a 61% increase, and the average of the subset of journals still listed in DOAJ rose to 1,800, close to double the 2011 price. Comparison of per-journal pricing in 2011 and 2021 shows that the average masks a more complex scenario where most prices are rising, while some remain the same and others decrease.

The weight of evidence strongly suggests an overall trend of rising prices well beyond inflation as OA journals become established and are successful in attracting content. This is particularly noticeable for journals that are listed in DOAJ and journals with higher impact factors. Authors are tending to choose to publish in more expensive journals. Charging and higher prices are associated with particular disciplines, particularly science, technology, and medicine. These pricing trends might be of concern to APC payers such as research funders, universities, and libraries.

The weight of evidence also suggests a functional and functioning economical OA alternative for those who pay directly or indirectly for scholarly journal publishing. Universities (as distinct from university presses) stand out as having the most OA journals, the highest percentage of non-charging journals, with APC journals tending to charge less. Although university journals tend to be smaller, collectively this

sector publishes the most articles. This evidence complements the findings of Bosman et al. (2021) and the recommendations of Becerril et al. (2021) based on a major survey of 1,619 “diamond” or no-fee OA journals that are financially supported by Research Performing Organizations (primarily universities) (p. 117), 40% of which are owned by universities (p. 79).

Limitations and further research

Both the 2011 and 2019-2021 datasets are drawn from the Directory of Open Access (DOAJ). While DOAJ is the most comprehensive vetted list of fully open access journals, the extent of DOAJ comprehensiveness is unknown and there is evidence to suggest that it represents only a fraction of the fully OA journals. Bosman et al. (2021, p. 7) estimate that there are about 29,000 “diamond” or no-fee OA journals, and only about a third of them are listed in DOAJ. Shi (2020) reports that a Chinese Open Access Aggregator makes about 10,000 OA journals available; these journals are not reflected in DOAJ. Other limitations associated with DOAJ are exclusion of journals that some would consider open access, such as hybrid subscriptions-open access journals, journals with free access to back issues, and journals that publish less frequently, for example journals associated with conferences that are held every other year. The quality of DOAJ metadata is another limiting factor, as is illustrated by the challenges of identifying publishers and publisher size based on variations in publisher name input and typos. Identifying a single per-journal APC represents a simplification of what is a complex variable, as variations in pricing based on such factors as author ability to pay, length and quality of wordsmithing, and society or institutional membership are common, and there is a growing tendency for large payers such as library consortia to negotiate one fee with publishers for journal subscriptions and OA to the works of their own authors. Combining datasets from different sources, developed by groups of researchers with similar but not identical methods, inevitably introduces some apples and oranges comparison type errors. We are confident however that despite these limitations some firm conclusions can be drawn, and directions suggested for further research. Further studies of APC trends should focus on price band analysis, per-country, per-currency, and/or per-publisher trends rather than global average APC, while further studies of economic models for OA might be better aimed at the potentially more economical university or research performing organizations sectors.

Conclusions

The APC business model is used successfully by a minority of fully open access journals, and is more common in particular subject areas, particularly science and medicine. The fact that half the APC charging journals listed in DOAJ in 2011 are no longer listed in DOAJ in 2021 demonstrates that a journal’s APC model and/or inclusion in DOAJ are not indicators of stability. Journals from the 2011 dataset that are still publishing showed price increases well beyond inflation rates, suggesting that an APC market could replicate the inelastic market long observed with subscription journals. Impact factor, measured by relative JCR or Scopus ranking, correlates with higher APCs. While the per-journal global average APC has increased at less than the rate of inflation, the per-article global average APC has increased at a rate far beyond inflation, and price band analysis indicates an overall concerning trend of price increases. Meanwhile, more OA journals and articles are published by universities (as distinct from university presses) than any sector, and this sector is associated with a greater tendency not to charge APCs, and when APCs are charged, to charge much lower fees than other sectors. This is a model worthy of further exploration.

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Publishers No Longer in DOAJ appendix

Publishers in DOAJ 2011 not 2021	# Journals
Academic and Business Research Institute	7
Academic Journals	8
Academy & Industry Research Collaboration Center (AIRCC)	21
Advanced Research Journals	3
AstonJournals	5
Bentham Open	72
Canadian Center of Science and Education	20
e-Century Publishing Corporation	6
Engg Journals Publications	3
European Journals, Inc.	3
Internet Scientific Publications, LLC	8
Kamla-Raj Enterprises	9
Maxwell Science Publication	11
OMICS Publishing Group	20
Scholarlink Resource Centre	3
Sciedu Press	4
Scientific Research Publishing	48
Total	251