



Article Processing Charge Hyperinflation and Price Insensitivity: An Open Access Sequel to the Serials Crisis

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Abstract

Open access publishing has frequently been proposed as a solution to the serials crisis, which involved unsustainable budgetary pressures on libraries due to hyperinflation of subscription costs. The majority of open access articles are published in a minority of journals that levy article processing charges (APCs) paid by authors or their institutions upon acceptance. Increases in APCs are proceeding at a rate three times that which would be expected if APCs were indexed according to inflation. As increasingly ambitious funder mandates are proposed, such as Plan S, it is important to evaluate whether authors show signs of price sensitivity in journal selection by avoiding journals that introduce or increase their APCs. Examining journals that introduced an APC 4–5 years after launch or when flipping from a subscription model to immediate open access model showed no evidence that APC introduction reduced article volumes. Multilevel modelling of APC sensitivity across 319 journals published by the four largest APC-funded dedicated commercial open access publishers (BMC, Frontiers, MDPI, and Hindawi) revealed that from 2012 to 2018 higher APCs were actually associated with increased article volumes. These findings indicate that APC hyperinflation is not suppressed through market competition and author choice. Instead, demand for scholarly journal publications may be more similar to demand for necessities, or even prestige goods, which will support APC hyperinflation to the detriment of researchers, institutions, and funders.

Keywords: open access; author choice; journal selection; article processing charge; price sensitivity; hyperinflation

1. Introduction

For over three decades, scholars and librarians have struggled with the cost of scholarly communication. From the 1980s, the hyperinflation of subscription costs imposed unsustainable pressure on library budgets (Houghton, 2001; Tananbaum, 2003). Open access was proposed as one way of coping with these costs because articles would not require ongoing subscriptions to remain accessible (Prosser, 2003; Tananbaum, 2003). Although concerns about the affordability of open access have been expressed (Green, 2019), others have argued that inflation of the article processing charges (APC) frequently charged to authors in gold open access models will be controlled by the price sensitivity of authors who can choose different outlets in a competitive market (Pinfield, 2013). The architects of Plan S, which would involve funders requiring immediate open access to funded outputs, are also concerned about APCs and have commissioned an independent study on the issue (Johnson, 2019).

However, there is no evidence that authors are sensitive to price when choosing their publication outlets. It has previously been shown that APC costs are correlated with journal prestige, as measured by source normalized impact per paper (Björk & Solomon, 2015; Pollock & Michael, 2019). Moreover, journal prestige and related indicators such as impact factor and indexing are frequently at the top of author considerations (Nicholas et al., 2017; Wijewickrema & Petras, 2017). These findings suggest that authors may be unlikely to consider cost very highly because the importance of publishing their work in the most “prestigious” outlet available is the most important component of their publishing strategy.

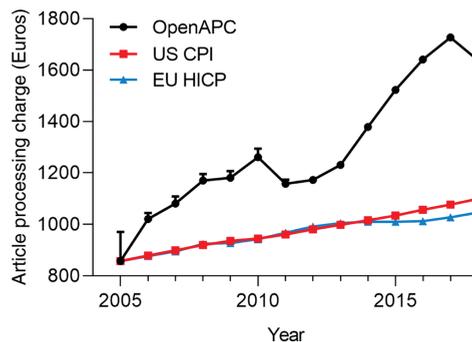
Authors also appear to choose APC-funded journals over free journals (also known as platinum or diamond open access journals). APC-funded journals comprise just 30% open access journals, but publish 56% of open access articles (Crawford, 2018a), a finding that has been replicated multiple times (Laakso & Björk, 2012; Walters & Linvill, 2014). However, this alone does not demonstrate that authors prefer APC-funded journals over platinum journals because in some fields there are no quality platinum options. For example, the Directory of Open Access Journals includes 32 journals with the DOAJ

Seal for the subject area of neurosciences, biological psychiatry and neuropsychiatry (as of March 2019). There is just one journal, added in February 2019, that is APC-free due to sponsorship by the Egyptian government. While in aggregate this aspect of open access might suggest authors prefer to pay to publish, it is circumstantial only and does not necessarily reflect price ‘competition’ within individual fields.

There is already evidence that APC hyperinflation is a real phenomenon. Data from 2005 to 2018 on the APCs paid by European institutions (Figure 1) shows that from a mean APC of €858 in 2005, APCs have nearly doubled, to over €1,600 in 2018 (Aasheim et al., 2019; <https://treemaps.intact-project.org/apc-data/openapc>). However, inflation as reported by the United States Bureau of Labor Statistics or the European Central Bank would only have increased the 2005 APC to a 2018 APC of €1,100 and €1,046, respectively. While this is not as severe as the nearly 5-fold increase in serial unit-costs between 1986 and 1998 (Houghton, 2001), it is an increase three times higher than what would be expected based on present economic conditions and suggests that the market for open access publications is not as competitive as Pinfield (2013) predicted.

It is therefore necessary to examine more direct evidence of whether authors are price sensitive when choosing journals. Many publishers increase journal APCs on a regular basis, for example, after the end of an introductory free period or upon being assigned an impact factor. If authors are sensitive to

Fig. 1: Article processing charges paid (mean±SEM, €) by European institutions between 2005 and 2018 compared to the 2005 fee indexed according to inflation in the United States (Consumer Price Index) and Europe (Harmonised Index of Consumer Prices). Data from OpenAPC as of 31 March 2019.



price, it would be expected that a journal introducing a fee for the first time would see a reduction in article volumes. When examining the portfolios of commercial publishers, it would also be expected that changes in the APC would be a significant negative predictor of the number of articles published by an individual journal.

2. Methods

2.1. Fee Introduction Case Studies

If authors are price sensitive with respect to APCs, then they might be expected to react the most readily when a journal transitions from charging no APC to levying an APC. Two notable cases of APC introduction were selected: eLife and Royal Society Open Science. eLife is commonly viewed as a prestigious journal launched to compete with elite titles like Nature, Science, and Cell (Callaway, 2016), while Royal Society Open Science is an example of an open access mega-journal or OAMJ (Björk & Catani, 2016; Khoo & Lay, 2018). Both of these journals are quite large, publishing more than 1,000 articles of all types in 2018. Article volumes were downloaded from Scopus, focusing on research articles that were published in final form, using a search string such as "ISSN(2050-084X) AND DOCTYPE(ar) AND PUBSTAGE (final)". Stepwise linear regression was performed using SPSS 25 (IBM, New York, NY, USA) with year and whether there was an APC as independent variables and the number of articles as the dependent variable.

Journals also introduce APCs when flipping from subscription publishing to open access publishing. In a recent conference paper, Momeni, Fraser, Peters, and Philip (2019) provided a dataset of journals that have flipped to open access. After excluding journals in this dataset that used hybrid or delayed open access models, or were not indexed by the DOAJ, 19 journals were identified where the flip year could be verified, and sufficient data on article volumes was available via the Crossref API to examine publishing volumes for 4 years prior and 4 years after flipping to open access. The Crossref API was used because many of these journals were not fully indexed in Scopus. Most journals (n=11) that flipped to open access charged an APC at the flip. Almost all of these journals were published by commercial publishers BMC (n=6), Springer Open (n=1), Wiley (n=2), and Wolters Kluwer (n=1), with one journal published by the society-owned Portland Press. Journals that did

not levy an APC at flip (n=8) tended to be published by non-profit or society publishers such as the American Library Association (n=1), Association of College and Research Libraries (n=1), IOP Publishing (n=1), Norwegian Polar Institute (n=1), and Spanish National Research Council (es: Consejo Superior de Investigaciones Científicas, n=3). Only one journal was published by a commercial publisher (BMC), with the journal supported by a national funder. Article volumes were analysed using a mixed-design ANOVA, with the 9 years around the flip as a within-subjects factor (time) and whether the journal levied an APC as a between-subjects factor. Following a significant violation of the assumption of sphericity for the within-subjects factor of time, the Greenhouse-Geisser correction was applied to the degrees of freedom for these effects.

2.2. Analysis of Fee Increases and Article Volumes

Authors might also be expected to respond to price increases that occur gradually over time. In order to test this, the APCs and article volumes of journals from major open access publishers were examined over several years. A study period of 2012–2018 was selected because data on historical APCs was publicly available (Crawford, 2018b) and could be combined and supplemented with searches of the internet archive (web.archive.org). The published APC in US dollars was used or converted to US dollars based on yearly average exchange rates published by the US Internal Revenue Service. Data on article volumes was downloaded from Scopus, using the journal's ISSN and excluding editorials, letters to the editor, commentaries, and articles that were still 'in-press', for example "ISSN(1932-6203) AND DOCTYPE(ar) AND PUBSTAGE (final)". Scopus was used to limit results to research articles because some publishers distinguish between different article types in their pricing.

The journals of BioMed Central Ltd (BMC), Frontiers Media SA, MDPI AG, and Hindawi Limited were analysed because they represent the 4 largest commercial open access publishers that use an APC business model, as measured by the number of articles indexed by the DOAJ. Journals from these four publishers were included if they were published from 2012 to 2018 by the same publisher and indexed by Scopus from 2012 to 2018. 134 BMC journals, 24 Frontiers journals, 54 MDPI journals, and 107 Hindawi journals were included in final analyses.

In order to determine whether APCs had an effect on article volumes, a multilevel modelling approach was used. Multilevel modelling is an extension of linear regression modelling that can be used to analyse multiple covariates longitudinally (Galla et al., 2014; Heck, Thomas, & Tabata, 2014). In the present study, a series of models were developed in SPSS, using a first-order autoregressive covariance type and maximum likelihood estimation. Journal was the unit level of analysis with the APC in US dollars and publisher group (BMC, Frontiers, MDPI, Hindawi, or OAMJ) as covariates, and the number of articles as the dependent variable. Beginning with the null model, the fixed factors of APC was added to the analysis. Publisher was included as a random effect. Model selection was performed using the likelihood-ratio test, which involves a χ^2 test of the deviance score or change in $-2 \log$ likelihood ($-2LL$), although Akaike's Information Criterion (AIC) is also presented for convenience (Gomes et al., 2014).

2.3. Data Availability Statement

The raw data underlying this study is available on Figshare (Khoo, 2019).

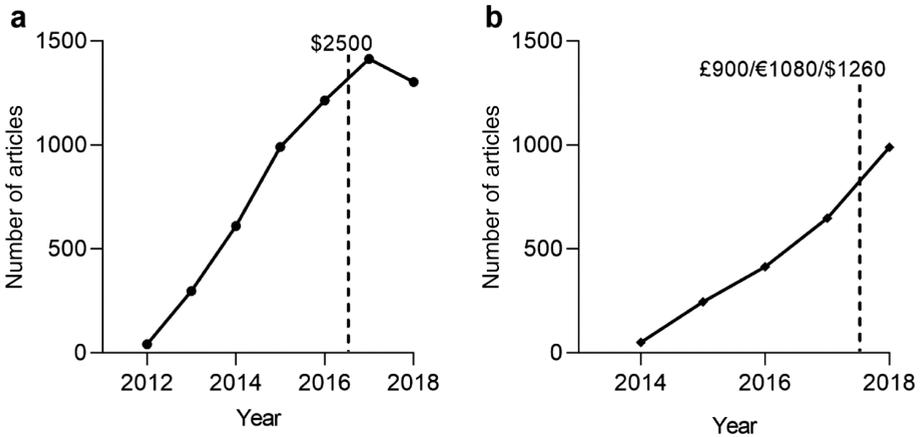
3. Results

3.1. Fee Introduction Case Studies

The introduction of an APC was not a significant predictor of the number of articles for eLife (Figure 2a). For eLife, stepwise linear regression produced a model ($R^2=0.926$, $F(1,6)=62.439$, $p=0.001$) with year as a significant predictor that was associated with increased article volumes ($\beta=236.4$, $p=0.001$). However, for Royal Society Open Science (Figure 2b) both year and APC were significant predictors ($R^2=0.998$, $F(2,4)=660.13$, $p=0.002$). However, both year ($\beta=196.2$, $p=0.002$) and APC ($\beta=159$, $p=0.037$) were associated with increases in the number of articles published by the journal.

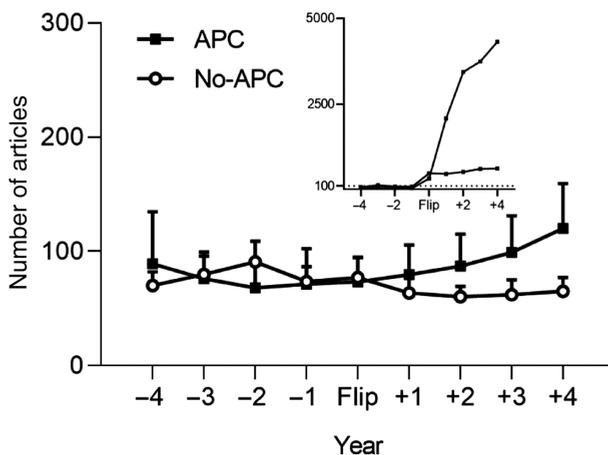
Another case of fee introduction occurs when journals flip from subscription models to open access models. In a dataset derived from Momeni et al. (2019), 19 journals were identified that flipped to open access models between 2006 and 2014. Two outliers were excluded from the APC group (final APC $n=9$, no-APC $n=8$) because their increase in article volume after

Fig. 2: The number of articles published in (a) *eLife* and (b) Royal Society Open Science was unaffected by the introduction of an article processing charge 4–5 years after launch.



flipping to open access was so large that 4 years post-flip, they were more than 4 standard deviations from the mean during the flip (flip year $M=109$, $SD=117$). As shown in Figure 3, there was no evidence that introducing an APC caused a reduction in article volumes. A mixed-design ANOVA showed

Fig. 3: There was no evidence that introducing an article processing charge during a flip to open access caused a reduction in article volumes (mean \pm SEM). In two outlier cases, journals that flipped and charged an APC greatly increased their article volume (see inset).



no significant change in article volumes over time ($F(3.116,46.741)=0.642$, $p=0.597$, $\epsilon=0.39$). Journals that levied an APC did not publish significantly more than journals that did not ($F(1,17)=0.177$, $p=0.684$). While two outlier journals experienced extremely strong growth in article volumes after flipping to open access (Figure 3, inset), there was not a significant pattern of this in other journals, with no $\text{time} \times \text{APC}$ interaction ($F(3.116,46.741)=2.298$, $p=0.088$, $\epsilon=0.39$).

3.2. Fee Increases Did Not Reduce Article Volumes

In the time between 2012 and 2018, the mean APC listed for each journal ($n=319$) by the four largest open access publishers (BMC, Frontiers, MDPI, and Hindawi) increased by US\$396 from US\$1,255 to US\$1,651 (Figure 4a). US inflation (CPI) during this time would have predicted an increase of merely US\$151 (12%) and European inflation (HICP) would have produced an even smaller US\$68 (5.4%) increase. MDPI had the largest increase in APCs of 220%, albeit, from a low base, while Frontiers increased prices by 40%, Hindawi by 34%, and BMC increased only slightly above US inflation at 17%. Despite APC growth of between 2.5 and 6 times inflation, total article

Fig. 4: (a) Mean \pm SEM article processing charges and (b) the number of articles published per journal per year both increased from 2012 to 2018.

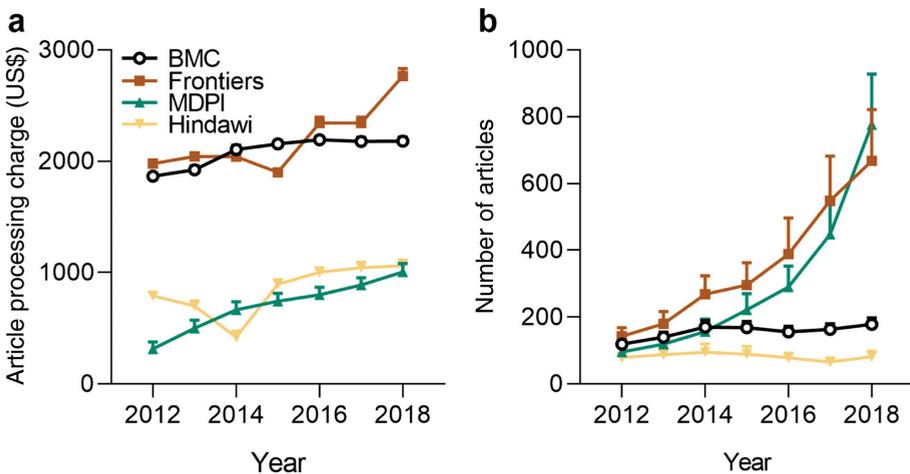


Table 1: Results of multilevel modelling for article volumes as a function of APCs and publishers from 2012 to 2018.

	Null model	Model 1
Fixed Effects		
Intercept	250.1±72.53, p=0.027	154±76.5, p=0.108
APC	–	0.0658±0.0102, p<0.001
Repeated Measures		
AR1 diagonal	154459.3±10915	145011±10272
AR1 ρ	0.93±0.005	0.93±0.006
Random Effects		
Intercept Publisher	18728.8±14879.2	20352.9±15724.1
Intercept Publisher×Journal	0±0	0±0
Information Criteria		
–2 log likelihood (–2LL)	29174.53	29134.05
Akaike’s information criterion	29184.53	29146.05

volumes more than doubled from 58,007 to 127,528 for these journals. As shown in Figure 4b, no publisher experienced a decrease in article volumes and Frontiers and MDPI appeared to be particularly successful in achieving growth in the number of articles per journal.

Multi-level modelling found that higher APCs were not associated with a decrease in article volumes, but were instead associated with an increase. Table 1 presents full results with parameter estimates and information criteria. The intraclass correlation coefficient from the null model for publisher-level effects was 0.108, indicating a non-significant proportion (10.8%, Wald $Z=1.259$, $p=0.208$) of the variation was between publishers. A lower –2LL indicated that model 1, which incorporated the journal’s APC as a fixed effect, was a superior fit than the null model ($\chi^2(1)=30.48$, $p<0.001$). This model indicated increasing APCs were associated with higher article volumes, with a US\$15–20 price increase being associated with an additional article per year ($\beta=0.0658$, $SE=0.0102$, $p<0.001$). Variance due to differences between publishers was not significant (12.3%, Wald $Z=1.294$, $p=0.196$).

4. Discussion

Increases in article processing charges at commercial publishers are proceeding at a rate far higher than inflation. Case studies of fee introduction

did not show any evidence that introducing an APC reduced the number of articles published either in an elite open access journal, an open access mega-journal, or in established journals that flipped to open access. A longitudinal study of 319 journals operated by four major commercial publishers, BMC, Frontiers, MDPI, and Hindawi, indicated that higher APCs are associated with higher article volumes. These findings suggest that authors are not sensitive to price in a way that can control APC hyperinflation.

The hyperinflation of list-price APCs for the four publishers examined in the present study is consistent with the APCs paid by European institutions and reported as part of the OpenAPC project (Aasheim et al., 2019). From 2012 to 2018, APCs paid by European institutions increased from €1,173 to over €1,600, or 40%. Similarly, overall APC increases by BMC, Frontiers, MDPI, and Hindawi was 31.6%, with publisher-specific increases of between 17% and 220%. These fee increases are consistently above inflation as reported by the US Bureau of Labor Statistics and the European Central Bank.

If authors weigh journal price heavily in their journal selection strategies, then it might be expected that APC-funded journals would struggle to become established and lower-APC journals would be favoured. While some journals have launched with an introductory no-APC period, such as eLife and Royal Society Open Science, the end of the introductory period did not prevent the journals from continuing to publish a large volume of articles, or continuing to grow. For journals that flipped to open access, there was no statistically significant effect of introducing an APC. While Momeni et al. (2019) noted that there was a post-flip decrease in article volumes, in the present analysis, this was only evident in a small and statistically non-significant decrease in non-APC-levying journals from $M=70$ four years pre-flip to $M=65$ four years post-flip. For APC-levying journals, a statistically non-significant increase from $M=89$ four years pre-flip to $M=120$ four years post-flip was observed, with two outlier journals increasing their volumes by 7 and 100-fold.

The longitudinal study of 319 journals from 2012 to 2018 confirmed and extended previous findings that suggested authors might not be price sensitive. If anything, authors appear to favour more expensive journals since the final model's estimate was that APC was a positive predictor of article volumes. This could be explained by the perceived association between

journal prestige and price (Björk & Solomon, 2015). In this market, a higher price is associated with higher prestige. Very low APCs in the order of US\$100 are even associated with potentially predatory journals, while legitimate open access journals levy fees closer to US\$2,000 (Shamseer et al., 2017). Given the importance of prestige and journal reputation in the academic publishing market (Nicholas et al., 2017; Wijewickrema & Petras, 2017), it seems logical that academic publications follow the principles of ‘prestige pricing’ or ‘status consumption’ where price increases can be associated with increased demand (Goldsmith, Flynn, & Kim, 2010; Kumcu & McClure, 2003).

A lack of price sensitivity appears unsurprising given that every APC-charging open access journal is facing competition from journals that are free-to-authors. Authors almost always have the option to submit to a subscription journal or one of the many platinum open access journals available (Crawford, 2018a; Laakso & Björk, 2012; Walters & Linvill, 2014). However, it can also be argued that in fact the majority of authors do choose subscription journals because the vast majority of articles are not immediately open access (Green, 2017, 2019). Moreover, of those authors publishing in hybrid subscription journals, more than 95% do not choose to pay an APC in order to make their article immediately open access (Laakso & Björk, 2016).

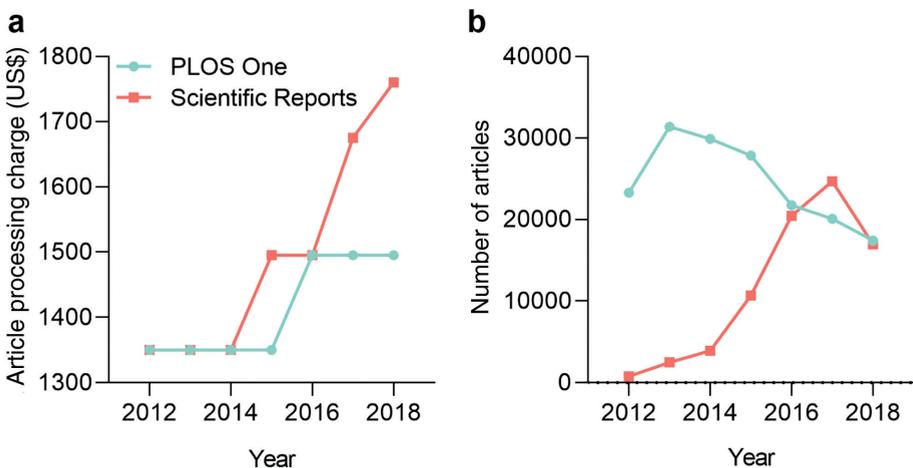
Authors may therefore assess APCs on a binary basis, assessing whether they can pay an APC but not weighing the magnitude of the APC. This approach would be consistent with both the results of the present study and with arguments that APCs exclude authors from less well-funded research groups (Shaw & Elger, 2018). Authors who are satisfied with their free-to-publish options may choose a subscription journal or platinum open access journal (subject to availability), but if they are able to, will likely choose to publish in an outlet that is commonly perceived as more prestigious, even if that means paying an APC or a higher APC. In this respect, authors may be treating publications more like a necessity. If publications are necessities, this would explain the negligible sensitivity that authors who can pay show towards APCs, much like how consumers will continue to purchase staple foods in the face of price increases (Kemp, 1998; Regmi & Meade, 2013).

It has previously been argued that paying to publish constitutes a conflict of interest for researchers (Tennant et al., 2016). In addition to potentially biasing

the editorial process (Beall, 2012, 2013; de Vrieze, 2018; Haspelmath, 2013), this also places authors in a potential conflict with the public interests (such as government or philanthropic funders) that support them. The author's own career interests and needs (more papers in more prestigious journals) may incentivise them to be more willing to pay an APC or to pay a higher APC, while as a steward of public funds they might be expected to publish using a lower cost open access model such as preprints or self-archiving.

The results of the present study also suggest that publishers are aware that they are able to set prices without adversely affecting their market share. For example, Springer Nature's open access mega-journal, Scientific Reports, overtook the non-profit PLOS One as the largest mega-journal in 2017 (see Figure 5), despite PLOS One charging a lower APC. Similarly, Frontiers and MDPI enjoyed the greatest growth in article volumes per journal and also increased their APCs by the highest margins. Publishers have freely admitted that they do not price on the cost of production, but rather on the economic value of their journals (Morrison, 2018), consistent with commentary in the scholarly publishing literature (Houghton, 2001). For example, once a journal is assigned an impact factor, its prestige value increases and it can therefore command a higher price. As open access journals become more established,

Fig. 5: (a) Article processing charges and (b) article volumes for PLOS One and Scientific Reports, which are the two largest open access mega-journals.



this should concern funders and institutions because it will drive further hyperinflation in the scholarly publishing market unless funders and institutions leverage their negotiating and policy-setting power to decrease costs (Else, 2018a; Gaind, 2019; Vogel & Kupferschmidt, 2017).

Price insensitivity leaves ambitious open access funder mandates like Plan S with few options for controlling publication costs charged by commercial publishers. Plan S proposes to cap APCs at some undisclosed amount (Else, 2018b). However, there is no single reasonable APC. Journals that are perceived as more prestigious tend to charge higher APCs (Björk & Solomon, 2015; Pollock & Michael, 2019), perhaps because they tend to have a higher rejection rate and APCs are only received for accepted manuscripts. Indeed, the President of the US National Academy of Sciences argues that their flagship journal would have to charge an APC of US\$6,000 purely for cost-recovery purposes (McNutt, 2019). Although one of the principles of Plan S is that APCs should be paid for by funders or institutions, societies still have concerns about cost barriers for authors (Guzik & Ahluwalia, 2019; Purton, Michelangeli, & Fésüs, 2019). With a uniform European APC cap, there appears to be no reason why the amount of the APC cap would not simply become the standard APC charged by publishers as they aim to maximise their revenue. Moreover, the cap cannot be set too low otherwise it will exclude funded researchers from the journals that are commonly believed to occupy the top tiers of their discipline. Publishers can then apply upwards pressure on the APC cap by raising their fees above it and forcing authors to seek out supplementary funding to publish in journals considered more prestigious (Purton et al., 2019).

Many societies see Plan S as a threat to their subscription journals, which may help to concentrate more of scholarly publishing with the largest commercial publishers. If societies sell their journals to commercial publishers (Brainard, 2019), this may further exacerbate APC hyperinflation. In subscription journal pricing, larger commercial publishers tend to be more expensive on a per page or per point of impact factor basis (Creaser & White, 2008). In the present study, commercial publishers were behind the majority of journals that flipped to open access and charged an APC, while non-profit publishers were behind almost all of the journals that flipped without charging an APC. Although the details of Plan S still appear to be under consideration, as originally announced it would have banned publishing in subscription journals, even if the individual article could be made open access under a hybrid

model, unless the journal was covered by a 'transformative agreement' (Else, 2018b; Johnson, 2019). Depending on the final details of Plan S, it will be important to examine what effects it has on the scholarly publishing ecosystem and its associated costs. For example, future studies could compare the present rate of APC hyperinflation to APC hyperinflation following Plan S implementation to examine whether the continued concentration of market power with commercial publishers will further accelerate price increases in scholarly publishing.

5. Conclusions

Open access publishing has been suggested as a potential solution to the serials crisis because journal costs are theoretically more exposed to price competition. However, examination of journal article volumes when article processing charges are introduced or increased over time shows no evidence that authors avoid journals that introduce or increase APCs. Instead, it appears that once authors are willing or able to pay an APC, that they are willing to pay them with little regard to the size of an APC. This data suggests that publishers are adept at pricing journals according to the prestige value of the title and the funding available to authors in each market. Unless funders and institutions leverage their negotiating and policy-setting power to constrain costs, author price insensitivity will ensure that APC-funded open access will merely be a sequel to the serials crisis.

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Conflict of Interest Declaration

The author has published with or reviewed for some of the journals or publishers or their competitors included in these analyses as part of their

regular academic duties and he is a reviewing editor at Frontiers in Behavioral Neuroscience (Frontiers Media SA). He is the founding president, an editor, and financial contributor to Episteme Health Inc., a non-profit incorporated association aiming to provide platinum open access publishing for neuroscientists. He has never received and does not expect to ever receive any payment for any of these roles.

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