



Article processing charges for open access journal publishing: A review

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Abstract: Some open access (OA) publishers charge authors fees to make their articles freely available online. This paper reviews literature on article processing charges (APCs) that has been published since 2000. Despite praise for diamond OA journals, which charge no fees, most OA articles are published by commercial publishers that charge APCs. Publishers fix APCs depending on the reputation assigned to journals by peers. Evidence shows a relationship between high impact metrics and higher, faster rising APCs. Authors express reluctance about APCs, although this varies by discipline depending on previous experience of paying publication fees and the availability of research grants to cover them. Authors rely on a mix of research grants, library funds and personal assets to pay the charges. Two major concerns have been raised in relation to APCs: the inability of poorly funded authors to publish research and their impact on journal quality. Waivers have not solved the first issue. Research shows little extension of waiver use, unintended side effects on co-author networks and concerns regarding criteria to qualify for them. Bibliometric studies concur that journals that charge APCs have a similar citation impact to journals that rely on other income sources.

Keywords: article processing charges, open access, scholarly communication

INTRODUCTION

Open access (OA) has shaken up scholarly communication in the past two decades by introducing a new publishing model based on the idea of free, unrestricted distribution of research outputs. There are two strategies to achieve this aim: green OA (i.e., the deposit of scholarly outputs in repositories) and gold OA.

In the gold OA model, journal publishers make articles immediately available for free on the web. To sustain their business, publishers require authors, instead of readers, to bear the costs of publication. Thus, gold OA journals charge article processing charges (APCs) to authors to make their work available in OA. However, not all OA journals charge APCs. Some journals, known as diamond or

platinum journals, are funded by other means, such as by learned societies and university presses. Nevertheless, most commercial publishers whose income has been based on selling subscriptions have implemented APCs. Some journals are fully OA, while others use a hybrid OA model that combines subscription content, which is paywalled, with OA for articles whose authors pay APCs.

This article reviews the literature on APCs published since 2000 to improve our understanding of their nature and their implications for scholarly communication. To the best of our knowledge, this is the first comprehensive review of this phenomenon since, in a review of economic aspects of the scholarly journal system, King and Tenopir (2011) devoted some space (pp. 340–347) to the ‘OA author pays’ model.

This review aims to provide a comprehensive summary of previous research on APCs. A clear understanding of the implications, controversies and challenges of APCs is crucial for the consolidation of the OA publishing model. This review also provides a starting point for researchers aiming to conduct further research on the topic.

The text is organized around eight issues. After describing the method employed to gather the literature, the nature of APCs to sustain OA publishing is introduced. Afterwards, research is summarized on the transition from journal subscriptions to OA based on APCs. The next section gathers studies on the prevalence of APCs, price models, fees charged and expense monitoring. Afterwards, a section is devoted to factors that determine how publishers set APCs. The review continues by revising the literature on funding sources used by authors to pay APCs. The following section covers studies on authors' views and behaviour regarding APCs. The final two sections deal with concerns on two questions: the inequities introduced by APCs and their potential impact on journal quality. All these issues are brought together in a conclusion that describes the role of APCs in the current scholarly communication landscape.

METHOD

On 9 May 2022, we conducted a search in Scopus to retrieve papers published since 2000 that included any of the following three expressions in the title, abstract or keywords: 'article processing charges', 'author fees' or 'publication fees'. We did not restrict the search by document type or language (Fig. 1). We considered searching the acronym 'APC', but most of the retrieved records were not relevant for our purpose.

After removing duplicates (i.e., records including two or three of the searched keywords), 497 results remained. We screened the articles' titles and abstracts and selected 232 results that matched our research topic. Non-pertinent records were mostly duplicates (i.e., two records in Scopus referring to the same document, Fig. 2A), similar results presented in a conference paper and a journal article (e.g., Fig. 2B), and abstracts including funding information for the payment of APCs (e.g., Fig. 2C).

After assessing the full-text of these 232 articles, we retained 168. Articles excluded at this stage were mostly studies on scholarly communication that mentioned APCs in passing, editorials announcing the introduction of APCs in a given journal, and case studies describing the OA landscape in a country or discipline. Based on backward and forward chaining of references and citations to these relevant documents, we added 17 articles to the review. Finally, on 11 July 2022 and 2 March 2023, we replicated our search and added three and six new results respectively; thus, a total of 194 papers were reviewed.

The scope of the review is limited by the coverage of Scopus, which has been criticized for its overrepresentation of English language journals and its underrepresentation of journals from the Global South (Borrego et al., 2023). This gap is important since the issue of APCs especially affects scholars based in

Key points

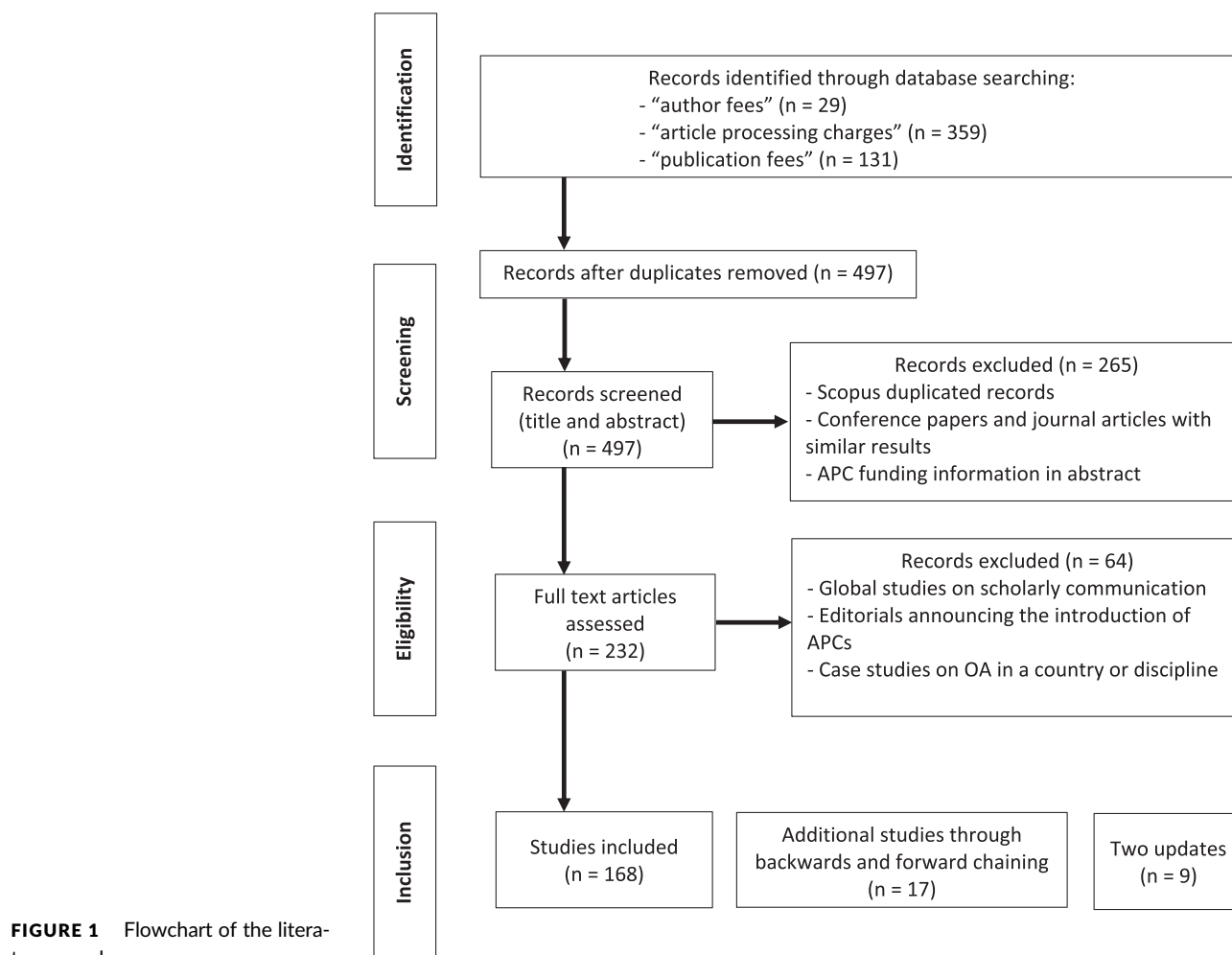
- Although diamond open access (OA) journals that charge no fees are prevalent, most OA articles are published by commercial publishers that charge article processing charges (APCs).
- The relationship between impact metrics and APCs evidences that publishers fix fees depending on the reputation assigned to journals by peers.
- Authors express reluctance about APCs, although this varies by discipline depending on previous experience in paying publication fees and the availability of research grants to cover them.
- As regards waivers, study suggests that their use is limited, that they may have unintended side effects on the composition of co-author networks, and that there are concerns regarding the criteria used to qualify for them.
- Bibliometric studies concur that journals that charge APCs have a similar citation impact to journals that rely on other sources of revenue.

countries with less access to research funds. We may also have missed relevant research results published in the form of grey literature, such as reports or dissertations not indexed in Scopus.

The revised studies had been published over the course of two decades, from 2003 to 2023, although 145 articles (75%) had been published in the last 10 years. Six journals concentrated one-third (32%) of the literature, each one publishing more than five articles on the topic: *Learned Publishing* (15 articles), *Scientometrics* (12), *Insights: the UKSG Journal* (11), *Journal of the Association for Information Science and Technology* (11), *Publications* (8) and *PeerJ* (6). Most authors were affiliated to institutions based in the United States (46 articles, 24%), the United Kingdom (27, 14%), Canada (12, 6%) and Germany (12, 6%). As discussed above, the geographical origin of authors needs to be borne in mind when analysing the results; the issue of APCs is especially relevant to researchers in countries and institutions with less access to research funds, but most of the literature has been published by authors based in wealthy nations.

THE APC MODEL TO SUSTAIN OA PUBLISHING

The origins of OA are related to what is known as the 'serials crisis'; that is, continuous increases in journal subscription prices above the rate of inflation and, as a consequence, the inability of



(a)	An Empirical Analysis of the Amount of Publication Fees	Hagenhoff, S., Blumenstiel, M., Ortelbach, B.	2008	Serials Review 34(4), pp. 257-266	9
	An empirical analysis of the amount of publication fees	Hagenhoff, S., Blumenstiel, B., Ortelbach, B.	2008	Serials Review 34(4), pp. 257-266	0
(b)	Freemium as a sustainable economic model for open access electronic publishing in humanities and social sciences	Mounier, P.	2011	Information Services and Use 31(3-4), pp. 225-233	2
	Freemium as a sustainable economic model for open access electronic publishing in humanities and social sciences	Mounier, P.	2012	ELPUB 2012 - Social Shaping of Digital Publishing: Exploring the Interplay Between Culture and Technology, 16th International Conference on Electronic Publishing	1
(c)	patients with CVD. Funding: No funding or sponsorship was received for this study. Sponsorship for article processing charges and open access fees was provided by Alfa Wassermann.				

FIGURE 2 Examples of records removed: (A) two records in Scopus referring to the same document, (B) similar results published in a journal article (top) and conference proceedings (down), (C) record including article processing charge funding information in the abstract.

research institutions to buy access to all the scholarly content required by their researchers. Within this context, the appearance of the internet seemed to provide an opportunity to meet two

objectives: to displace commercial companies from the journal publishing market and to save part of the money devoted by research institutions to the acquisition of scholarly information

resources. In the words of Getz (2005, p. 2) 'substantial cost savings to universities are possible with open-access distribution of quality-assured journals by not-for-profit publishers whose rates reflect cost rather than each university's ability to pay'. Other OA proponents did not intend to displace commercial publishers and advocated that costs of publication should be viewed as costs of research and assumed by funding agencies (Falk, 2004; Gass, 2005).

Most OA journals in the 1990s were based on voluntary work and used the editors' university web servers for free, combined with the allocation of government grants to support local scientific journals (Björk, 2011; Laakso et al., 2011). It was not until 2002 that commercial publishers entered the OA market, relying on APCs as their income source. BioMed Central, founded in 2000, was the first professional OA publisher (Björk, 2011). It launched a large number of journals in the fields of biology and medicine and introduced APCs in 2002. Initially, the standard APC was about US \$500 for accepted manuscripts, which was adjusted 'to a more realistic £750 in July 2005' (Cockerill, 2006, p. 154). The enterprise was successful enough to be acquired by Springer in 2008.

When BioMed Central introduced APCs across its portfolio of journals, numerous editorials were published to justify this decision. The publisher stated that, since authors obtained the reward for publication, it was logical that they 'cover the costs of peer review and publication' (Schnelle et al., 2003, p. 218). In addition to underlining the benefits of access without economic barriers, to other scientists and the general public, the publisher gave three reasons to justify the APC model: it was more sustainable than the traditional subscription model and its price increases beyond inflation and library budgets (Marincola, 2003; Schnelle et al., 2003); authors retained copyright so the article could be published freely on the web, submitted to interested readers and colleagues and article components could be utilized in other publications without a request for permission (Bukovsky & Bazer, 2003); and free online articles were cited more because of their greater availability (Mathers & Murray, 2003; Velterop, 2003).

In addition to these arguments, most editorials stated that, since BioMed Central journals were not printed, they did not levy page charges or charges for colour illustrations, which was a common practice at the time. Print journals frequently levied page charges for amounts similar to the newly established APCs and both charges were sometimes conflated. Thus, Doyle, Gass and Kennison (2004, p. 409) stated that publication fees were 'not a phenomenon born of the open-access movement. Many authors regularly pay several thousands of dollars in page charges, color charges, correction costs, reprint costs, and other fees to their publisher'. Cockerill (2006, p. 151) described APCs as 'not unlike the page charges levied by many subscription journals'. AGU, a non-profit scientific association publishing journals in earth and space science, announced the arrival of APCs as a substitute for colour charges (Cook, 2010).

Most BioMed Central editorials highlighted the concession of waivers and discounts to referees and authors from developing countries or low-funded institutions, so APCs would 'only be paid by those who can afford it' (Bukovsky & Bazer, 2003). In addition, an automatic waiver was provided if the author's institution was a BioMed Central member. We will return to APC centrally paid models and waivers below.

Besides a potential reduction in costs, some authors predicted that the adoption of APCs would result in redistribution of these costs among research institutions. The reason was that institutional disparities in research outputs were far greater than institutional differences in library holdings. If research institutions assumed the costs of their members' publications in OA journals funded with APCs, a shift from a pricing model based on subscriptions to one based on publishing productivity would reduce the proportion of the total cost paid by most institutions and increase the proportion of the total cost paid by the largest research universities (Walters, 2007; Walters & Wilder, 2007). Any potential cost reduction would not be linear at institutional level since the revenue model in the two systems was different. With subscriptions, the reader base determined the institutional costs, whereas with OA the number of authors was decisive (Waaijers, 2015).

This redistribution of costs among research institutions is usually referred to as the 'free rider' problem. As the share of OA outputs increases, less research-oriented institutions are tempted to cancel their subscriptions. The money they contributed to the scholarly communication market through subscriptions disappears from the system and research-intensive institutions have to cover the difference through APCs. Nevertheless, not all authors agree with the idea that library budgets in research-intensive institutions would suffer from additional stress in the transition from subscriptions to OA. In the United States, the 'Pay it Forward' project (Cook & Smith, 2017) explored costs associated with moving scholarly journal subscriptions entirely to an APC business model. They estimated that, if all journals shifted to gold OA, the more research-intensive universities would pay more than they paid for journal subscriptions. However, those institutions also enjoy large research grants and many of their researchers already pay publishing fees in the form of submission fees, page fees, colour charges, and so on from their grants. Therefore, library budgets would not necessarily require more funding, since research grants could offset some costs. In Germany, Bruns et al. (2020) compared options for sharing costs for publication in APC journals and their financial effects at institutional level. They distinguished four sharing options depending on whether costs were assumed by the institution of the first author, that of the corresponding author, distributed equally among institutions, or weighted on the number of authors from each institution. They concluded that all models resulted in similar expenditure for the overwhelming majority of institutions, although there were organizations where the difference between the most and the least expensive model was a considerable amount.

THE TRANSITION FROM JOURNAL SUBSCRIPTIONS TO OA PUBLISHING BASED ON APCs

A lot of the literature has investigated possible transitional models from journal subscriptions to OA publication. From the perspective of publishers, Laakso et al. (2016) identified various scenarios for journals transitioning from subscription to OA. Among the models that rely on APCs, three general conversion scenarios were identified (introducing submission fees, bundling APCs with subscription licences and rebranding the scope of the journal) and two gradual conversion scenarios: hybrid OA and delayed OA.

Hybrid journals seemed a promising model that would allow publishers to flip their business from selling subscriptions to publishing OA. The idea was that authors would progressively pay fees for publishing their articles OA and, as a result, publishers would reduce subscription prices until the full journal converted to OA. An editorial in *Gerontechnology* (Van Bronswijk, 2013, p. 2) illustrates this approach. The editor 'urge[d] authors to use our voluntary OA publishing [€800], to pave the road to full OA'. The publisher intended an increase of 25% in voluntary OA each year to reach full OA in 4 years.

Björk and Solomon (2014) explored ways for funders to cover the cost of APCs, while encouraging the development of a competitive, transparent market. They claimed that gold and hybrid OA markets were 'significantly different' (p. 101): gold OA was a 'relatively normal economic market', with publishers competing via a combination of quality, innovative services and price, whereas hybrid OA was 'dysfunctional' with little price differentiation among journals based on quality, discipline or services provided. Similarly, Besancenot and Vranceanu (2017, p. 149) claimed that this move towards hybrid OA resulted in 'higher revenues for the MPHs [major publishing houses], a reduced burden for libraries, and high costs for authors'. Nevertheless, the hybrid model spread widely, with the number of journals offering this option increasing from around 2000 in 2009 to almost 10,000 in 2016 and the number of articles growing from 8000 to 45,000 (Björk, 2017). A study using article metadata showed that the share of Elsevier hybrid OA articles increased from 2.6% to 3.7% between 2015 and 2019 (Jahn et al., 2022). Most hybrid OA articles were invoiced directly to authors, followed by articles invoiced through agreements with research funders, institutions or consortia, with only a few funding bodies driving hybrid OA uptake.

Concerns about higher APCs in hybrid journals than in gold journals were further exacerbated by the perception that publishers offering hybrid OA were 'double dipping'; that is, receiving payment to make an article OA and a second payment for the same article in the form of a subscription for the remainder of the journal (Kingsley, 2014). In contrast to previous statements on the potential savings of OA, Verhagen (2013, p. 53) considered it necessary to 'accept that OA is substantially more expensive than subscriptions for HE [higher education] institutions that

contribute above average to the production of scholarly information'. He proposed two possible solutions to avoid disruptions caused by hybrid OA. These solutions anticipated what subsequently have been transformative agreements: to include clauses in journal subscription licences to provide researchers with heavily discounted APCs or to provide free access to journals by agreeing to pay the full APCs for university members' publications in the publisher's journals.

Concerns about higher APCs in hybrid journals and the 'double dipping' issue have reached research funders, who increasingly mandate OA for the results of the research they fund. In 2018, a consortium of national research agencies and funders from 12 European countries launched Plan S, which required researchers who benefited from grants to publish their work OA. As a result, an increasing number of publishers and libraries have negotiated transformative agreements, also known as 'offsetting', 'read and publish' or 'publish and read' agreements (Borrego et al., 2021). These contracts bundle subscription licences with APCs and aim to shift the focus of scholarly journal licensing towards OA publication. The assessment of the first transformative agreements in the market showed that, although they had slowed down increases in costs and could help institutions in the administration and implementation of OA, they were also 'flawed through their implicit acceptance and strengthening of the current costly and opaque market for journal subscriptions' (Earney, 2017, p. 11). An analysis of a sample of 36 transformative agreements (Borrego et al., 2021) concluded that it was hard to assess whether these agreements were just a temporary phase in the transition towards OA or would perpetuate the current structure of the scholarly communication system and its associated high costs.

The shrink in journal publishing costs due to technology has not resulted in library savings but has increased publishers' revenue due to drawbacks in the scholarly communication market to the point that 'judicious policy intervention in the journal market is worthwhile' (Armstrong, 2015, p. 1). OA has often increased library expenditure for institutional repositories and payment of APCs and library support for OA is often more of a 'philosophical stance' (Holley, 2018), without significant cost savings. Some authors believe that APCs funded by academic library collections' budgets are 'antithetical to the values of librarianship and academic libraries' (Scott, 2018, p. 262). According to Willinsky (2018), OA has taken two forms, either a commercial model dominated by large traditional publishers pursuing APCs or non-profit initiatives supported by research institutions. Willinsky and Rusk (2019) argue in favour of the second, moving towards universal OA without APCs. Similarly, Green (2019) suggests that flipping to supply-side business models, such as APCs, will not work with current budgets. He proposes adopting a two-step publishing model where articles are published first as preprints, then journal editors invite authors to submit papers that 'succeed' for peer review.

Leaving aside the impact of APCs on library budgets, some research has explored other side effects of APCs. Although there is not much data available on how the introduction of APCs

affects the number of submissions to gold OA journals, an editorial by Bachelet (2019) reported that their introduction in the biomedical journal *Medwave* resulted in a 50% drop in the number of unsolicited manuscripts between 2016 and 2018. However, an analysis of four large gold OA publishers (Khoo, 2019) showed no evidence that APC introduction reduced article volumes. APCs may also have an impact on how authors create co-authorship networks. Using Multidisciplinary Digital Publishing Institute (MDPI) journals as a case study, Cary and Rockwell (2020) found that researchers from low-income countries were more likely to form international collaborations than researchers from wealthier nations, possibly to cover the costs of APCs.

PREVALENCE OF APCs, PRICE MODELS, FEES CHARGED AND EXPENSE MONITORING

Several studies have analysed the prevalence of OA journals that rely on APCs as a source of revenue, their price models, the fees they charge and the expenses of research institutions. They concur that APCs are associated with large publishers (Polydoratou & Schimmer, 2010) and that OA journals based on APCs are larger than OA journals without author fees. In an analysis of 663 OA journals in six subject areas, Walters and Linvill (2011b) reported that 29% of OA journals charging APCs published 50% of the articles, with journals in biology and medicine being larger and more likely to charge fees. Similarly, Laakso and Björk (2012) observed the increasingly common presence of OA journals charging APCs. They were responsible for the publication of 49% of all OA articles in 2011. Kozak and Hartley (2013) reported that 28% of over 9000 OA journals listed in the Directory of Open Access Journals (DOAJ) charged authors for publishing. This figure was much higher in medicine (47%) and the sciences (43%) than in the humanities (4%) and the arts (0%). These figures have remained stable. Using DOAJ data from 2018, Gul et al. (2019) reported that 27% of journals charged APCs. Rodrigues et al. (2020) focused on 1354 journals that had received the DOAJ Seal; that is, they had achieved a high level of openness and publishing standards (around 10% of the journals listed in DOAJ). Within this group, 72% of journals charged APCs, most of them (59%) less than US \$1000. Crawford conducted a series of studies on gold OA journals listed in DOAJ. The overall picture in 2021 (Crawford, 2022) identified 16,620 OA journals: 68% charged no fees, but 69% of the articles were published in journals that did charge APCs.

Instead of DOAJ, Kim and Park (2021a, 2021b) used the Journal Citation Reports (JCR) as a data source. They observed that, in 2019, gold OA journals accounted for 13% of the journals listed, while hybrid and subscription-only journals represented 67% and 20%, respectively. Gold OA journals were further divided into 1323 journals with APCs and 317 without. About 2 million OA articles were indexed in the Web of Science between 2014 and 2019, which accounted for 21% of all articles (17% in gold OA journals and 4% in hybrid journals).

Regarding price models, after analysing data from 77 publishers charging APCs, Björk and Solomon (2012b) concluded that the most frequent pricing method was a single fee for all articles in a particular journal, with 70% of publishers using this model. This APC either could be the same for all the journals of a given publisher or individually determined for each journal. Fees were only applied to accepted papers. Journals charging submission fees were 'rather uncommon' (p. 134). This latter practice has continued to be exceptional and, based on DOAJ data from 2018, Gul et al. (2019) reported that just 246 journals charged submission fees and 125 journals charged both submission and publication fees compared to 3256 journals that charged only publication fees.

In terms of fees charged, most studies concur that there is a wide price range, with hybrid journals charging higher APCs than gold journals. Two sources are used to collect this information: prices advertised by publishers on their websites and requests for information from authors and institutions about the fees they have paid. Using the first approach, Solomon and Björk (2012a) analysed 1370 DOAJ journals that charged APCs. The average APC was slightly over US \$900 (with fees ranging between US \$8 and US \$3900), a much lower figure than was generally charged by subscription publishers for providing individual articles OA in hybrid journals. Professionally published journals had substantially higher APCs than journals published by societies, universities or scholars/researchers.

A longitudinal series of studies estimating APCs was conducted by Morrison and colleagues. An initial study (Morrison et al., 2015) observed that 26% of the journals listed in DOAJ in May 2014 charged APCs. Their analysis described a 'complex', 'volatile' landscape with a wide range of publication costs, variation in pricing (including waivers and discounts for authors based in low-income countries), different prices depending on article type, institutional or society memberships, optional charges for extra services such as language editing or fast track, and so on. Afterwards, Morrison et al. (2016) published an updated dataset with data collected in 2015. More recently, she reported that the global average APC showed little change over time: US \$906 in 2010, US \$964 in 2016 and US \$974 in 2017 (Morrison, 2020). However, this average masked currency differences and the impact of a growing market, with new OA journals often starting with an APC of 0. A further study (Morrison et al., 2022) examined trends in APCs from 2011 to 2021 and concluded that most journals still do not charge them. The average APC per journal increased slightly, but the average per article increased from US \$904 to US \$1626, indicating that authors chose to publish in more expensive journals. Crawford (2022) reported that the average cost per article in DOAJ journals, including journals that charge no fees, was US \$1374 (US \$1997, considering only APC-based journals).

Solomon and Björk (2016) triangulated APC data on publications by authors based at four research-intensive universities in the United States and Canada with APC payment records from several European universities and funding agencies. They found that the gold APC average was slightly under US \$2000 while the

hybrid APC average was about US \$3000. The study illustrates how, in addition to gathering price data from publishers' websites, another source of information on publication fees is self-reported data on APC payments. The OpenAPC initiative (openapc.net) gathers datasets on fees paid for OA publication. The data are provided voluntarily by research institutions and funders. Using this source, Jahn and Tullney (2016) estimated an average APC in Germany between 2005 and 2015 of €1298. Most articles published in gold OA journals charged lower fees than hybrid journals. In contrast, articles in hybrid journals accounted for the largest share of spending in Austria and the United Kingdom, according to the same source. Pieper and Broschinski (2018) provided additional insight into OpenAPC's technical and organizational background and illustrated how transparent, reproducible reporting on APC expenditure can be conducted across institutions and publishers. Nevertheless, Bruns and Taubert (2021) showed that, for German universities contributing to this monitoring system, more than half of APC payments were not covered. The average payments for non-covered APCs were higher than for covered APCs, and the group of universities that did not contribute to OpenAPC accounted for two thirds of APC-liable publications in the country.

Some studies have aimed to calculate APC expenditure at country, funder, disciplinary or publisher level. In India, Madhan et al. (2017) estimated that, between 2010 and 2014, researchers spent around US \$2.4 million annually on APCs to publish about 15,400 papers in gold OA journals (i.e., excluding hybrid OA), with prices ranging from US \$7.5 to US \$5000. White et al. (2021) studied journal articles published by researchers at all eight New Zealand universities in 2017. They estimated an average cost of US \$1682 for gold OA articles and US \$2558 for hybrid OA articles, to reach a total estimated cost of US \$1.45 million. In Chile, Krauskopf (2021) estimated expenditure above US \$9 million for 2019 publications that included at least one Chilean affiliation, with over 52% of the APCs collected by five commercial publishers.

At funder level, Bakker et al. (2017) analysed the OA publishing costs of articles funded by the Multiple Sclerosis Society of Canada between 2009 and 2014. Their results evidenced significantly lower APCs in gold (US \$1900) than in hybrid (US \$3000) journals. At disciplinary level, Peñaranda-Ortega et al. (2021) calculated the cost of OA publication of all the articles in JCR journals in the top two quartiles in psychology between 2017 and 2018. They estimated an average APC of €2321 and a total cost of around €68 million per year. Another study that focused on the cost of OA articles published via APCs by Spanish authors in five areas of the social sciences between 2012 and 2019 (Ferrer-Sapena et al., 2021) estimated an average APC of €1129 with a total cost of €481,120. Smith et al. (2017) calculated that the amount paid in APCs for global health research published between 2010 and 2014 was US \$1.7 million for 627 papers, with authors paying on average US \$2732 per publication and 94% of APCs charged by the 10 most prominent publishers. Concurring with the latter result, Kim and Park (2020) reported an estimated average APC for the top 10 publishers in the JCR of

US \$2652. For all 10 publishers, except Elsevier and the Royal Society of Chemistry, the average APC per article was higher than the average journal subscription price. Finally, Butler et al. (2022) estimated that authors paid the five largest commercial publishers \$1.06 billion in gold and hybrid publication fees between 2015 and 2018.

Going one step further, a series of studies in the United Kingdom aimed to provide a picture of the total cost of publication (i.e., subscriptions plus APCs and administration costs) incurred by academic institutions. Initial results showed a rapid rise in APC payments between 2007 and 2014, although with considerable variation across institutions and publishers. The average APC over the period was £1682 and the top 10 publishers received 76% of the payments made. On average, APCs accounted for 10% and subscriptions for 90% of the total cost of publication, excluding administration costs (Pinfield et al., 2016). Another study (Johnson et al., 2016) reported that the cost to make an article OA using the gold route was over 2.5 times higher than the green route (i.e., depositing in a repository) and that the costs of complying with research funders' OA policies were considerably higher if publication was left entirely to the authors' discretion. Subsequently, using data from 2012 to 2014, Pinfield et al. (2017) showed that APCs constituted 12% of the total cost of publication, APC administration 1%, and subscriptions 87%. The average APC in 2014 was £1586, with hybrid options considerably more expensive than gold OA.

From a methodological point of view, Gray (2015) argued that research to calculate the total cost of publication neglected other publication charges, predominantly page and colour charges. When these charges were considered, the total cost to British institutions as of 2013–2014 was around 18.5% above the cost of journal subscriptions: 11% from APCs, 5.5% from indirect costs and 2% from other publication charges. In Spain, Baquero-Arribas et al. (2019) estimated APCs paid by the Spanish National Research Council (CSIC) between 2008 and 2018. CSIC authors had published their OA articles in gold and hybrid journals alike, although with an increasing slight predominance of the latter option. The sum devoted to APCs (€2.6 million) and the annual cost of subscriptions (€6.4 million) reached a total budget invested in scientific journals above €9 million.

The APC publishing model has been associated with the potential for more transparency and competition, leading to a more efficient market and cost reductions. However, research shows that this has not been the case. Hagenhoff et al. (2008) estimated the fees needed for journals to be sustainable based on the assumption that all serials changed their business model to author pays. They concluded (p. 257) that 'the amount of money currently available in the system of scholarly communication is probably not sufficient for the sustainable financing of publishing fees'. This assertion heavily contrasts with the conclusion of a subsequent report by the Max Planck Society (Schimmer et al., 2015) that stated exactly the opposite: 'all the indications are that the money already invested in the research publishing system is sufficient to enable a transformation that will be sustainable for the future. There needs to be a shared

understanding that the money currently locked in the journal subscription system must be withdrawn and repurposed for open access publishing services' (p. 1). These discrepancies possibly stem from the different perspectives adopted: that of the resources devoted by libraries or that of the profits expected by publishers. When Copiello (2020) analysed the transition towards a fully OA publishing landscape from the perspective of a big commercial publisher (Elsevier), he concluded that, to preserve the publisher's profit margin, average APCs would need be around twice (US \$4173–US \$4482) the current APC (US \$2544).

DETERMINANTS OF APCS

Another relevant question is how publishers set APCs. As discussed above, OA was initially envisioned as an opportunity to restrain licence subscription prices. However, it soon became evident that the 'author-pay model is not without its own pricing' (West et al., 2014, p. 1315) and APCs are subject to price increases similar to or higher than those of serial subscriptions. Khoo (2019) showed that, for four large gold OA publishers (BMC formerly BioMed Central, Frontiers, Hindawi and MDPI), APC increases proceeded at a rate three times faster than inflation. Zhang et al. (2022) estimated that revenues from APCs among major publishers exceed US \$2 billion annually, with expenses sharply increasing across a sample of six countries independently of their OA performance and policies.

The reasons behind APC increases are similar to those that explain serial subscription rises. Publishers set prices for subscriptions and APCs that do not correspond to the cost of publication, but to the reputation of their journals and the libraries and authors' ability to pay. Eve (2015) argued that the APC model is based on two key flawed assumptions. The first is that a market will emerge in which researchers will develop price sensitivity in the selection of their publication venues. However, in markets that deal with symbolic capital, such as prestige or reputation, perceived value has little to do with the services or goods provided, but instead is wholly concerned with how the brand is valued by peers. The second flawed assumption is that APCs are simply a straightforward substitution of the point of payment to the supply side of the economic system.

The correlation between APCs and prestige was identified by Walters and Linvill (2011a), who observed that journals that charged higher publication fees were especially likely to have higher impact factors. Later, Solomon and Björk (2012a) analysed 1370 journals listed in DOAJ that charged APCs. They observed that the lowest prices were charged by journals published in developing countries whereas the highest were charged by journals with high impact factors from major international publishers. In a subsequent study using bibliometric information provided by Scopus (Björk & Solomon, 2015, p. 381), they insisted on the relationship between citation rates and APCs and hypothesized that 'authors choose OA journals that offer better value in terms of impact for the APC paid'.

It is hard to find transparent information on publishers' costs and how these costs are transferred to APCs. Graziotin et al. (2014) analysed 30 OA journals in software engineering and information systems and concluded that high APCs were not sufficiently justified by publishers. Among the scarce examples of transparency, an editorial of the *Journal of Applied Medical Physics* (Mills, 2016) detailed the cost of the editorial platform, perpetuity, copyeditor, and so on to justify the introduction of a US \$500 APC, which is much lower than the charges of other journals in the same field.

There is further evidence of the relationship between APCs and prestige. Ennas and Di Guardo (2015) analysed a sample of 1910 gold OA journals and observed that, although 62% of journals did not require a publication fee, 61% of top-ranked journals required one. Using a sample of 174 OA non-human biological science journals, Gray (2020) showed that bibliometric values increased as APCs increased, and these metrics were higher for publishers from high-income countries. Taking MDPI as a case study, Okagbue et al. (2020) reported that the charges levied by journals that had an impact factor and CiteScore were significantly higher than those charged by journals with neither an impact factor nor CiteScore. Similarly, using OpenAPC data from the United Kingdom, Schönfelder (2020) found a positive relationship between the citation impact and APCs for gold and hybrid journals. Using DOAJ data, Siler and Frenken (2020) observed that journals published by large for-profit publishers with 'status endowments' (i.e., impact factor, DOAJ Seal) and those published in English, in wealthier regions, and in medical or science-based disciplines were more expensive. Budzinski et al. (2020) corroborated that journal reputation, the market power of publishers, the hybrid model and the concentration of disciplines increased APCs. Specifically, their results disclosed a 50% surcharge on hybrid OA publishing. Very similar results were reported by Maddi and Sapinho (2022), who showed that APCs for hybrid journals were on average 50% higher than for gold journals.

Some studies report disciplinary exceptions to this general trend. Demeter and Istratii (2020) showed a positive relationship between APCs and impact factors for journals in area studies and anthropology, but not in computer science. The reason could be that, in computer science, a significant number of journals are published by resourceful international associations. A study by Jamorabo et al. (2021) of a sample of gastroenterology journals found no association between APCs and higher impact (or faster processing times).

Asai conducted a series of studies on this topic by analysing the pricing models of a sample of gold OA publishers. First, he observed that BMC set higher APCs for more frequently cited journals and lower charges for recently launched journals (Asai, 2019, 2020a). A subsequent study (Asai, 2020b) confirmed that OA publishers set higher APCs for more frequently cited journals with more articles. These results suggest that publishers considered factors other than costs when they revised APCs. However, while this was true for BMC, it was not for Hindawi, which did not consider citation scores as a factor in revising charges (Asai, 2021a).

Finally, Ellingson et al. (2021) showed the relationship between prestige and APCs using a different approach. They estimated the financial costs paid by individual medical researchers in 2019 for meeting the APCs levied by OA journals. They compared a sample of 'general researchers' (with a median annual expense of US \$191) to a sample of 'high impact researchers' (with a median annual expense of US \$2900).

FUNDING SOURCES TO PAY APCs

Multiple studies have aimed to determine the sources authors draw on to pay the APCs for their publications. In most cases, researchers have been surveyed to gather information about how frequently they use grant funding or personal funds to pay APCs. In addition, libraries have established agreements with publishers to obtain discounts and facilitate the administration of payments. Some funders manage the payments of APCs for the research they fund.

One of the first studies on this issue (Swan & Brown, 2004) observed that 36% of a sample of authors who had published OA had paid a fee that was covered by their research grant or institution. An additional 19% had the fee waived by the publisher, a figure that may seem very high at present but made sense at an early stage when publishers were introducing APCs. Solomon and Björk (2012b) surveyed a larger sample of 1038 authors who had published in OA journals that charged APCs. Their results showed large differences in the source of funding among disciplines. As discussed above, journals with impact factors charged higher APCs, as did journals in disciplines where grant funding was plentiful (i.e., bio and physical sciences). In contrast, authors in the social sciences and humanities and those from lower income countries resorted to personal funds much more frequently. In a subsequent study, Solomon (2014) surveyed authors who had published in four OA megajournals and found significant differences among them. About half of authors of *PLOS ONE*, a third of *BMJ Open* and *PeerJ* and 10% of *SAGE Open* had used grant funding to pay APCs. Meanwhile, around 60% of *SAGE Open* and 32% of *PeerJ* authors self-funded their publication fees.

Wang et al. (2015) used a different approach to deal with the same issue by comparing OA articles in health sciences published in journals with and without APCs (i.e., diamond journals). The share of grant-funded articles increased as the APCs increased. Using a small sample, Cantrell and Swanson (2020) explored the range of funding sources available to and used by 22 authors in arts, humanities and social sciences based at three US universities. Although the authors expected that researchers in these disciplines would have limited access to sponsored research funding, the results showed that funding was available and used to pay APCs. Similarly, Halevi and Walsh (2021) surveyed authors at a US school of medicine and found that about half of them anticipated APCs costs in grant applications, whereas 16% paid APCs using personal funds.

As the APC publishing model became popular, research institutions took action to facilitate OA publishing to their members

and to deal with the administrative burden of managing payments. They reached agreements with publishers and provided funds to their members to allow them to publish in the OA venues of their choice. Since BioMed Central was the first publisher to exploit the APC model at large, it was also the first publisher to introduce membership programmes. It introduced two models (Cockerill, 2006) that allowed institutions to prepay future APCs for their members, which were debited at a discounted rate, or to pay a fixed price in return for which their members received a discount. By 2006, the APC was covered by institutional membership for 69% of articles published by BioMed Central where an APC was payable.

Academic and research libraries set up OA central funds to facilitate OA publication to their members. One of the earliest examples was the Nottingham Central Fund (Cockerill, 2009), established in response to OA mandates from research funders, although it enabled all authors to apply for funds to publish in OA journals. A central fund made it easier to manage and monitor payments for the institution. Other examples of APC central funds were those at the University of Glasgow (Ashworth et al., 2014; Nixon et al., 2013), University College London (Ayriss et al., 2014; Sharp, 2014), Royal Holloway University of London (Pontika & Rozenberga, 2015), the Max Planck Society (Sikora & Geschuhn, 2015) and Brunel University London (Walters, 2016).

Although individual case studies on these programmes are numerous, the model did not reach all academic libraries. A study by Pinfield and Middleton (2012) reported that, by 2011, only 13% of higher education institutions in the United Kingdom had an institutionally co-ordinated approach to pay APCs. The reasons for this lack of enthusiasm were diverse. For example, with institutional repositories in place, some institutions might have felt that they had fulfilled their obligations by providing a mechanism to support green OA. Demand from authors for support to pay APCs was still limited. Furthermore, a widely held belief among authors was that OA publication was less prestigious. In the United States, Monson et al. (2014) conducted a qualitative study of small and medium-sized academic libraries and observed that faculty publication funds were still a new concept in scholarly communication. In a subsequent study, Pinfield and Middleton (2016) analysed the adoption of an institutional central fund at the University of Nottingham using Innovation Diffusion Theory as an explanatory framework. They found that increasing awareness and changing perceptions of OA, communication, disciplinary differences and mandates were among the key factors in adoption.

Gillies (2014) described two approaches to negotiate hybrid publishing through library consortia: the 'market determinative approach', a scholar community initiative that imposes pricing for targeted journals on behalf of the end user community, and the 'consortium discount approach' where library consortia negotiate with commercial publishers. Horava and Ward (2016) surveyed international library consortia's approach towards APCs. The results described a new, volatile environment, where libraries took a cautious approach to balance their wish to support OA and lower the barriers to free dissemination of knowledge and research.

New library initiatives have arisen in recent years to support centralized APC payments. Reinsfelder and Pike (2018) described a publishing scheme based on a crowdfunding model for libraries and institutions to help local authors pay APCs. The model allowed libraries to share the cost of OA, often at a fraction of the cost of APCs. Other library programmes to fund APCs are targeted to support certain OA venues. The 'Fund for Fair Open Access', set up by KU Leuven Libraries in 2018 (Verbeke & Mesotten, 2022), was devoted to stimulating the development of non-profit and community-led initiatives, such as supporting diamond journals and subsidizing OA books published by Leuven University Press.

While most of the literature describes library initiatives to help authors pay APCs, Doney and Kenyon (2022) presented the results of a study to assess one of these programmes. They surveyed researchers who had received funding from, or showed interest in, an OA subvention fund at the University of Idaho. Participants expressed their support for the programme but also indicated an interest in establishing a more equitable fund distribution cycle and allowing researchers to seek pre-approval once their article had been accepted for peer review.

Finally, research funders have developed programmes to pay APCs for the results of the research they fund. Not many studies take the view of research funders and the burdens that the APC model imposes on them. Nevertheless, when surveyed about OA publishing based on APCs, medical research charities showed their concerns about the financial costs it imposes on them (Pinfield, 2013). Similarly, in a letter to *Nature*, Wood et al. (2021) stated that APC 'presents a financial threat to environmental non-governmental organizations'. De Castro (2016) and De Castro and Franck (2019) described a funder programme for APCs. In the first half of 2015, the European Commission launched a funding initiative to cover the APCs of publications arising from Seventh Framework Programme projects. This pilot programme also aimed to implement an alternative funding mechanism by which funding would also be offered to APC-free OA journals.

AUTHORS' VIEWS AND BEHAVIOUR REGARDING APCS

The success or failure of OA in general and the APC model in particular is intrinsically associated with its acceptance or rebuttal by authors. Therefore, numerous studies have aimed to collect information on authors' views and behaviour regarding APCs using quantitative and qualitative approaches.

Most authors' studies share two main findings: a relatively high level of rejection of APCs in the early stages that has only partially disappeared as the model has consolidated and significant disciplinary differences related to the availability of research funds to pay author fees. A major international survey conducted shortly after the introduction of the model (Nicholas & Rowlands, 2005, p. 181) found that 'half [the authors] said they were not prepared to pay anything [to have their work

published]'. Similarly, only 17% of a sample of surveyed authors who had published in OA education journals had paid APCs and over 56% indicated they would not publish in journals requiring such fees (Coonin & Younce, 2010). Focusing on mathematicians, Fowler (2011) observed 'substantial philosophical opposition to OA journal models that charge author fees'. Warlick and Vaughan (2007), who interviewed biomedical faculty members identified as early adopters of OA at two major American research universities, provided the only major disagreement. Their results showed that, for researchers in biomedicine, APCs were not a major barrier or disincentive. This may be because in this field author fees were not limited to OA publishing venues and included page and colour charges.

Most studies conclude that OA is a relevant factor when authors choose a publishing venue, but less important than other variables. In their survey of authors who had published in OA journals that charged APCs, Solomon and Björk (2012b) found that, although significant, OA was a less important factor than the fit of the manuscript within the subject area of the journal, scientific quality of the journal and speed of review and publication. Cusker and Rauh (2014) surveyed the physical sciences, engineering and mathematics faculty at two American research universities. The results indicated that most respondents had not decided against publishing in an OA journal due to APCs. Responses combined cautious optimism about OA journals with scepticism about their quality, and intense opposition to the idea of having to pay any additional costs from their own pockets. Similarly, Sandesh and Wahrekar (2017) surveyed faculty staff from three medical and five dental institutions in India and reported that publication fees were among the main criteria to consider in journal selection, but behind journal indexing, online submission, impact factor and the peer-review process. Nelson and Eggett (2017) focused on author motivations to publish in chemistry hybrid OA journals. Their results showed that authors primarily chose OA because of funding mandates. However, most considered the money well spent because OA increased information access to the scientific community and the general public, and potentially increased citations. Drawing on group discussions and interviews in the field of biomedical and health informatics, Greussing et al. (2020) observed that APCs and quality issues were perceived as the main obstacles for OA publishing.

The geographical factor is relevant in this kind of studies, since the economics of the region where scholars are based has an impact on the availability of research funds and, consequently, on their ability to pay APCs. In Africa, Olusegun et al. (2015) surveyed Nigerian medical academicians about how they choose their article venues. Indexing was the most important determinant of journal choice, but most respondents were unwilling to pay more than US \$300 as an APC. Similarly, Adjei and Owusu-Ansah (2016) explored the factors responsible for publication preferences among a group of researchers attending a research writing workshop in Ghana. Although the major factor influencing journal selection was its reputation, most researchers indicated a high preference for journals that did not charge APCs. Van Hoving and Brysiewicz (2017) surveyed members of the African

Federation of Emergency Medicine and found that 24% were not willing to publish in OA journals that requested APCs, while 39% would only consider OA journals if the fees were sponsored. In Pakistan, Sheikh (2019) revealed that faculty members used OA venues more frequently to access scholarly content rather than to publish their own research works. Lack of awareness of publishing in OA venues and publication fees were the key challenges faced by authors. In a survey of science and technology researchers in India, high APCs were cited as the most significant barriers to OA publishing (Nazim & Ashar, 2022).

In France, Schöpfel et al. (2016) revealed a gap between generally positive opinions about OA and less support towards paying APCs. Only 30% of surveyed scientists at the French National Research Centre (CNRS) declared that they had paid APCs, and less than 20% of the others intended to do so in the future. A subsequent study (Boukacem-Zeghmouri et al., 2018) confirmed that OA publishing was not the norm among French researchers, and that more than half of those who published in gold APC journals were members of editorial teams. Tenopir et al. (2017) surveyed academics at four major US research universities. The prevailing attitude towards APCs was ambivalence, with willingness to pay depending on the availability of funding. A survey of Spanish researchers (Ruiz-Pérez & Delgado López-Cózar, 2017) reported that nearly 70% had published at least one OA article in the previous 5 years. Half of these authors covered APCs with research funds. A subsequent study among a sample of philosophers (Feenstra & Delgado López-Cózar, 2022) concluded that they were reluctant to pay APCs since author fees raised doubts and suspicions about the potentially distorting effects on two issues reviewed below: equality of opportunity for authors and the integrity and quality of manuscript evaluation systems.

Finally, some studies focused on specific types of authors: academic librarians (Baro & Eze, 2017; Bosah et al., 2017; Neville & Crampsie, 2019), doctoral students (Prasojo et al., 2019; Purwanto et al., 2020) or early career researchers (O'Hanlon et al., 2020). These studies concur that the lack of funding for APCs is one of the main barriers to OA publication.

INEQUITIES INTRODUCED BY APCs

The literature evidences that OA publishing based on APCs suffers from three potential problems. The first, frequently referred to as the 'free rider' problem, has already been discussed. It relates to charges introduced by the OA publishing model that push institutions that produce the most scientific research to pay a larger share of the costs of the scholarly communication system.

The other two threats are related to the 'publish or perish' atmosphere in scientific research. First, there is a need to cover APCs for many authors. This is challenging in countries and institutions with few resources, given that the APCs increase above the rate of inflation. This evokes the 'serials crisis' in journal subscriptions. Second, some authors argue that APCs may introduce a conflict of interests. This affects scholarly journals that may be

tempted to reduce the rigour of peer review to accept more articles and increase revenue. In the worst-case scenario, predatory journals who spot an opportunity for profit may abuse authors. In this section, we will discuss the inability of some authors to pay the fees charged by journals. In the next section, we will review literature on concerns regarding the potential impact of APCs on journal quality.

Beasley (2016) criticized APCs because they represent a substantial economic barrier to the authors, institutions, funding agencies and governments that OA advocates wish to serve. Similarly, Alizon (2018) claimed that expensive APCs threatened less-funded departments and article quality. In the words of Green (2019, p. 14), 'replacing big subscription deals with big APC deals simply flips inequity in accessing content with inequity in publishing content'. Concerns regarding the inequity introduced by APCs have been frequently raised in opinion pieces. In a letter to the *Journal of the Royal Society of Medicine*, Sharma and Sharma (2010) expressed their disagreement with this model and their belief that authors from the developing world would not be willing to publish in journals with APCs. They noted that, in health sciences, APCs put more stress on junior students and residents at the beginning of their careers who are in need of these publications to further their chances of an academic position. They suggested that journals charging APCs should request a statement disclosing where the funding has come from. In another letter to *Nature*, Kapovich (2012) expressed similar concerns: 'Making authors pay to publish their research endangers the open and egalitarian nature of the scientific enterprise. Researchers in developing countries, unaffiliated researchers, graduate students and faculty members without large federal grants could all be priced out of publishing their work'. In the words of Shah and Gul (2013, p. 224), APCs have 'created a scholarly gap between those scholars who get the financial support and those who are either deprived of the financial support or get a very small amount that cannot meet their needs'. Likewise, Frank, Foster and Pagliari (2023, p. 1) insist on the inequities that the APC model presents 'for junior or unfunded researchers, and academics from resource-poor environments, for whom an increasing body of evidence shows clear evidence of discrimination and injustice'. Similar problems have been described for researchers in Africa (Chilimo et al., 2017; Mekonnen et al., 2022; Nabyonga-Orem et al., 2020; Raju & Pietersen, 2017), India (Jain et al., 2021) or Syria (Abdul Baki & Alhaj Hussein, 2021). At disciplinary level, Wright (2019) states that not all environmental science receives funding from large institutions and a lot of work, especially in developing nations, is undertaken on small grants from environmental non-governmental organizations. In a recent opinion piece, Alperin (2022, p. 233) argues that governments, funders and institutions should stop supporting APCs and should invest funds in shared infrastructure, tools, and services that can sustain multiple journals simultaneously. Such an embrace of diamond OA 'could lead to virtuous cycles in which journals can lower operating costs, raise their quality and elevate their place in research assessment'.

Some authors have conducted empirical research to determine to what extent these concerns about potential inequities introduced by APCs are real. Kieć (2017) surveyed authors in countries with a gross domestic product *per capita* that is less or greater than US \$18,000 ('periphery' and 'core' countries, respectively). Authors from periphery countries published their articles more often in gold OA and paid APCs equally often as those in core countries. Reasons were complex but it seemed that, for authors from the periphery, OA venues published in their own countries were the best option. Thus, about 52% of all journals listed in DOAJ in 2015 were published in countries with GDP *per capita* less than or equal to US \$18,000.

In another study, Eilers et al. (2017) observed that, from 2011 to 2015, countries with developing economies had a disproportionately greater share of articles published in the lower-tier megajournals and thus paid APCs that cross-subsidized publications in the top-tier journals of the same publisher. Conversely, scientists from Western developed countries had a disproportionately greater share of articles published in the same top-tier journals. Using global health research as a case study, Siler et al. (2018) observed that authors working at lower-ranked universities were more likely to publish in paywalled journals and less likely to choose either gold or hybrid journals involving APCs. In turn, Olejniczak and Wilson (2020) reported that the likelihood for a scholar to author an OA article with APCs increased with male gender, employment at a prestigious institution, association with a STEM discipline, greater federal research funding and more advanced career stage. Similarly, Asai (2021b) analysed authorship of articles in four disciplines and showed that authors in low-income countries published more in gold OA, whereas authors from high-income countries published more in hybrid OA. Using Elsevier's 'mirror journal' system, in which a hybrid 'parent' journal and its gold OA 'mirror' share editorial boards and standards for acceptance, Smith et al. (2022) showed that most OA articles were written by authors in high-income countries, whereas there were no articles in mirror journals by authors in low-income countries. APCs proved to be a barrier to OA publication for scientists from the Global South. A further case study of Elsevier's 22 pairs of parent and mirror journals (Asai, 2023) found that 72% of OA articles in 2021 were published in parent journals with high citation scores and APCs, suggesting that authors 'with sufficient financial support for open access' do not respond to fluctuations in APCs when choosing journals. After analysing 1.5 million articles from journals listed in DOAJ, Klebel and Ross-Hellauer (2023) provide additional evidence on how APCs stratify OA publishing, perpetuating the system of cumulative advantage inherent to academia, given that well-funded research groups are better placed to secure OA publications in prestigious journals with high APCs. This in turn generates citation advantages and leads to further funding down the line.

Cole et al. (2023) identified high costs of APCs as one of the issues undermining open research. In fact, this issue proved to be the most controversial when they used a Delphi method to provide recommendations on how to combat open research

inequities. Ultimately, they proposed recommendations pertaining to APC caps, increasing waiver programmes, and encouraging researchers to publish in alternative outlets and/or to use criteria other than prestige when selecting a journal. Some OA publishers waive APCs for authors from low-income countries as a measure to overcome these inequities. However, there is not much research on the extension of this practice. Analysing data from 77 publishers, Björk and Solomon (2012b) reported that 22% provided waivers and others charged lower APCs to authors from developing countries. A further analysis of a sample of 32 publishers that charged APCs (Lawson, 2015) showed that 69% had an explicit fee waiver policy. Taubert et al. (2021) concluded that, in economic terms, it was possible for a publisher such as Springer Nature to waive APCs for 47 low-income countries. However, an assessment of oncology journals (Gardner et al., 2021) found that journals with hybrid OA status, higher APCs, and those from the USA were seemingly less likely to offer APC waivers to authors based in lower- and middle-income countries. For a sample of articles published in 2020 in four disciplines, Asai (2021b) reported that authors benefiting from waivers accounted for less than 1% of the total.

As far as research results show, benefiting from a waiver does not influence the editorial management of an article. An analysis of articles published by *BMC Research Notes* (Uddin, 2014) reported that all submissions, either from countries with waivers or without, were treated equally in terms of time to be accepted by the publisher, that is, no sense of priority worked in the case of submissions from non-waiver countries.

Some authors claim that criteria to qualify for a waiver are not necessarily fair and may have side effects. Edem et al. (2021) reviewed the conditions for APC waivers or discounts in 13 major global health journals and concluded that their policies had implications for co-authorship since, for instance, articles with an author from a high-income country did not qualify for any form of APC waiver or discount. Similarly, Jain et al. (2021) claimed that India does not come under the waiver category for most of the journals that ask for APCs.

THE IMPACT OF APCs ON JOURNAL QUALITY

In addition to the inequities introduced by APCs, some authors are concerned that author fees may introduce a conflict of interests that leads journals to lessen the rigour of peer review to accept more submissions and increase revenue. These concerns are as old as the APC model itself. In 2004, the Science and Technology Committee of the House of Commons in the United Kingdom required universities to ensure that their scholarly papers were freely available online. When OA journals funded by APCs were discussed, the report noted 'concern that the author-pays publishing model would compromise the integrity of peer review' in a situation where journal revenues depended on the number of articles published, rather than the

number of readers who subscribed (House of Commons, Science and Technology Committee, 2004, p. 80).

Jeon and Rochet (2010) were among the first to study this problem from a theoretical point of view. They built a model of a journal to meet a double role of certification and dissemination of knowledge and showed that, for the journal to maximize social welfare, OA was optimal because the marginal cost of providing access to a reader was zero. However, the move from a subscription model to an APC model also affected the journal's quality standard for a not-for-profit journal and a for-profit journal. Traag and Waltman (2019) disagreed with this view and claimed that journals continue to have an incentive to maintain a certain quality to attract more submissions.

Empirical studies to explore the real extent of this potential laxity in peer review have employed two alternative methods. The most usual approach is to compare the citation impact of journals that charge APCs either with subscription journals or with OA journals without APCs. Frequently, these studies aim to determine whether OA journals are more cited than subscription journals, to show an 'open access citation advantage' resulting from their higher visibility. The second approach consists of submitting fake manuscripts to journals that charge APCs to observe whether these submissions are filtered through the peer review process.

Using the first approach, Björk and Solomon (2012a) compared the impact of OA and subscription journals framed in 'an ongoing debate as to whether the proliferation of open access (OA) publishing would damage the peer review system and put the quality of scientific journal publishing at risk'. After controlling for discipline (medicine and health vs. others), age of the journal and location of the publisher (the four largest publishing countries vs. other countries), the results showed that OA journals funded with APCs were more cited than other OA journals. In another study, Solomon et al. (2013) observed that 2-year citation averages for journals funded with APCs had reached the same level as subscription journals. Citation averages of OA journals funded by other means continued to lag well behind OA journals funded by APCs and subscription journals. The authors hypothesized that this was less a quality issue than due to the fact that such journals were commonly published in languages other than English and tended to be located outside the four major publishing countries.

Sotudeh and colleagues conducted a series of studies on the topic comparing OA routes. Sotudeh et al. (2015) explored the supposed citation advantage of the author pay model, using data from Elsevier and Springer (i.e., including gold and hybrid journals) between 2007 and 2011. They reported a citation advantage of OA journals that could be attributed to their higher visibility but that might also have roots in the selectivity of the authors in choosing the author pay outlet to publish their high-quality papers. A subsequent study (Sotudeh & Estakhr, 2018) confirmed the citation advantage of Elsevier hybrid OA journals for the 2012–2015. A third study (Sotudeh et al., 2019) reported that the combination of hybrid and green resulted in an intensified OA citation advantage. Finally, Estakhr et al. (2021) confirmed

the citation advantage at country level of hybrid OA articles published by Elsevier.

Zhang and Watson (2017) studied how researchers funded by the Canadian Institutes of Health Research complied their OA policy. They observed that hybrid journals had a higher citation rate than OA journals with APCs. On the other side, diamond OA journals had a much lower citation rate than the other two categories. Similarly, Abbasi et al. (2019) reported that Library and Information Science hybrid journals received more citations than gold OA and subscription journals. In contrast, Pollock and Michael (2019) claimed that gold OA journals attained higher impact factors at faster rates than subscription and hybrid journals.

Ghane et al. (2020) compared the citation performance of OA journals that do and do not levy APCs. They found that, overall, APC and non-APC OA journals had equal impact, although with disciplinary differences. Amjad et al. (2022) confirmed the citation advantage of OA articles published in APC journals published by Elsevier and Springer in four domains of computer science.

Some research suggests that the correlation between APCs and impact at journal level does not necessarily extend to article level. Looking at the impact of a sample of 83,752 papers, Maddi and Sapinho (2022) found that, 'contrary to common belief', paying high APCs did not necessarily increase the impact of publications.

Leaving aside bibliometric studies, other authors have used fake manuscripts to empirically assess the thoroughness of the peer review process in OA journals that charge APCs. Bohannon (2013) submitted a fake scientific article to a large number of fee-charging OA journals and revealed that less than 40% lived up to their promise of rigorously peer reviewing what is published. Dell'Anno et al. (2020) aimed to 'unmask' the inadequacy of the review process of a sample of fee-charging journals in economics. They submitted a 'bait-manuscript' to 73 economic journals to test whether there was a difference in the peer-review process between a treatment group (34 APC-charging journals) and a control group (39 traditional journals that did not require APCs). About half of the APC journals accepted the manuscript and the authors concluded that the 'traditional' model 'has a more effective incentive-mechanism to select based on quality standards'.

OA megajournals that apply a peer review policy based solely on scientific soundness have also been under scrutiny. Some authors are sceptical and believe megajournals are a publication outlet for lower quality papers that would not pass the stricter peer-review criteria applied by more selective traditional journals (Domnina, 2016; Spezi et al., 2017; Teixeira da Silva et al., 2019). Some studies have investigated whether this 'soundness-only' quality control may be linked to a higher rate of published errors. Erfanmanesh and Teixeira da Silva (2019) found wide variation in published errata and retractions across 16 megajournals between 2012 and 2018. An analysis of publishing behaviour and citation rates of prolific Spanish authors (Borrego, 2021) suggested that they do not submit to megajournals for the purpose of gaining easier publication in a high-impact journal.

In the worst-case scenario, some journals may simply obviate any kind of peer review and accept any manuscript to charge APCs. These journals are known as 'predatory', a term coined by Beall (2012). Similarly, journal hijacking consists in creating a fake website by mimicking an authentic journal portal, thereby defrauding scholars for a publication fee. The topic of predatory and hijacked journals goes far beyond the purpose of this review and merits a review on its own.

CONCLUSIONS

The economies of scale of OA digital publishing seemed to bring an opportunity to deter the continuous increases in serial subscription prices. Going one step further, some authors envisioned OA as an opportunity to shake up the scholarly communication market and displace commercial publishers. Their role would be assumed by non-profit societies and universities that would fund OA journals that charge authors, if necessary, with relatively small fees to cover the real costs of publication. This line of work has proved partially successful, and diamond journals and those charging low APCs are prevalent in DOAJ. However, most OA articles are published in journals owned by large commercial publishers that charge APCs. Nevertheless, the wide range of author fees charged by gold OA journals suggests that the dichotomic distinction between 'diamond journals' (no APCs) and 'journals charging APCs' is not fully enlightening. Some journals that charge small fees are possibly closer to the diamond ideal of providing a non-commercial venue for sharing research rather than to the for-profit business of commercial publishers.

Other OA proponents did not take such a radical view and assumed that journal publishing has costs that should be recovered. They contended that APCs should be covered by research funders as part of research costs, or by libraries, offsetting expenses previously devoted to subscriptions. Nevertheless, there were expectations that a change in publishing model could still reduce costs. The notion was that APCs would bring about a more competitive, transparent market than subscriptions. Whereas the cost of subscriptions for reading the literature was invisible to researchers, they would be aware of the costs of APCs and would become sensitive to prices when a publishing venue was chosen for their research. For research-intensive institutions, the adoption of the APC model would result in higher costs.

Over the past two decades, commercial publishers adapted their business model to include APCs, although the switch from journal subscriptions to OA publication has not been completed yet. Some transitional models, such as hybrid OA, have proved to be harmful to research institutions, with hybrid journals charging higher APCs than gold journals and no reductions in subscription prices, leading institutions to 'double dipping'. So far, there is no evidence that transformative agreements, which bundle subscription licences with APCs, have reduced library expenses.

In the current 'publish or perish' atmosphere, publishers enjoy the market power that allows them to charge APCs above

the cost of publication. Commercial publishers fix APCs depending on the reputation assigned to journals by peers. There is ample evidence of the relationship between high impact metrics and higher and faster rising APCs. Even if researchers develop any price sensitivity in selecting publication venues, they make decisions based on the value assigned to journals by research assessment committees that frequently reward publication in high impact factor journals.

Research on authors' views regarding APCs and the sources they use to pay them show large disciplinary variation. Most authors express reluctance about this publishing model, except for researchers in the medical and natural sciences who are used to paying publication fees and have greater availability of research funds. To pay APCs, authors rely on a mix of research grants, library funds and personal assets.

Two major concerns have been raised in relation to APCs: the inability of poorly funded authors to publish their results and their potential negative impact on the quality of journals. In response to the first issue, publishers state that they provide waivers, although research shows little extension of their use, unintended side effects on the composition of co-author networks and concerns regarding which criteria are used to qualify for them. As regards journal quality, the concern raised by the application of APCs is that author fees may introduce a conflict of interests that leads journals to lessen the rigour of peer review so as to be able to accept more submissions and thus increase revenue. Since it is not possible to observe how journals internally manage the review of manuscripts, authors who want to explore the real extent of this potential laxity in peer review have compared the citation impact of journals that charge APCs with that of journals that do not. Most of these studies concur that there are no differences in citation impact between journals based on APCs and journals relying on other sources of revenue.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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