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The Oligopoly's Shift to Open Access. How the Big Five Academic Publishers Profit from Article Processing Charges

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Abstract

This study aims to estimate the total amount of article processing charges (APCs) paid to publish open access (OA) in journals controlled by the five large commercial publishers Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley between 2015 and 2018. Using publication data from WoS, OA status from Unpaywall and annual APC prices from open datasets and historical fees retrieved via the Internet Archive Wayback Machine, we estimate that globally authors paid $1.06 billion in publication fees to these publishers from 2015-2018. Revenue from gold OA amounted to $612.5 million, while $448.3 million was obtained for publishing OA in hybrid journals. Among the five publishers, Springer-Nature made the most revenue from OA ($589.7 million), followed by Elsevier ($221.4 million), Wiley ($114.3 million), Taylor & Francis ($76.8 million) and Sage ($31.6 million). With Elsevier and Wiley making most of APC revenue from hybrid fees and others focusing on gold, different OA strategies could be observed between publishers.

Keywords: open access; article processing charges; academic publishing market; big five academic publishers; Unpaywall; Web of Science

1. Introduction

Since the early 2010s, over half of all peer-reviewed journal articles have been published by a few for-profit companies that control the majority of scholarly publishing and contribute to an oligopolistic market structure (Larivière et al., 2015). While initially focusing on subscription models—leading to the serials crisis and big deals that libraries could no longer afford—these commercial publishing houses have now embraced open access (OA). Although removing paywalls is certainly a step in the right direction to providing access to scholarly literature, large publishers generally approach OA based on the author-pays model, which often involves article processing charges (APCs) that contribute to existing inequities that exclude many from publishing (Chan et al., 2020; Harle & Warne, 2019; Olejniczak & Wilson, 2020; Siler & Frenken, 2020).

Since Elsevier, Sage, Springer-Nature, Taylor & Francis, and Wiley are for-profit shareholder companies with profit margins in excess of 30% (Larivière et al., 2015; Taylor, 2012; Van Noorden, 2013), a significant amount of fees that authors pay to publish are not justified by the actual costs related to the publication process itself (FOAA, n.d.).

This study focuses on the APC revenues generated by Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley by analyzing the number of gold and hybrid OA journal articles and associated publication fees during the 2015-2018 period. Specifically, we aim to answer the following research question:

a. How much has the academic community paid these publishers for publishing gold and hybrid OA articles over the 2015-2018 period?
b. Which journals obtain the largest amounts of total APCs?
c. How do the number of gold and hybrid articles and the associated amount of APCs differ between countries and academic disciplines?

2. Literature Review

2.1 Open Access models and trends

OA emerged in the 1990s with the acceleration of digital technologies and the establishment of the world wide web. The Budapest Open Access Initiative (BOAI, 2002) granted OA its most famous definition as scientific literature that is publicly available online, free of charge, unrestricted, discoverable, free of most copyright and licensing restrictions, and available for reuse (BOAI, 2002). It initially suggested two main methods of OA dissemination, namely via repositories or publisher journal websites.

Dozens of models have emerged since the early days of OA (Willinsky, 2006). The more common ones include gold, green, and hybrid (Eve, 2014; Suber, 2012; Willinsky, 2006). Piwowar et al. (2018) introduced bronze OA to reflect the increasing occurrence of free-to-read articles on publishers' websites without licensing information. Diamond OA is a community-driven model where journals do not charge authors a fee to publish (Becerril et al., 2021). Since diamond OA describes gold OA journals without APCs, we consider diamond OA as a particular subset of gold OA where the APC amount is unknown since these fees are not paid by authors butcovered by

organizations such as universities, national funding or government agencies or learned societies (Bosman et al., 2021). The different OA models are not always mutually exclusive; for example, gold OA articles might also be green if they are self-archived by authors. The combination of models, such as "Green-via-Gold," was recently discussed in the context of the White House Office of Science and Technology Policy (OSTP) Public Access memorandum issued in August 2022 (Hinchliffe, 2022; OSTP, 2022; Schonfeld, 2022).

Gold OA represents articles published in journals which make all articles free to read on the publisher's website upon publication (Archambault et al., 2014; European Commission, 2019; Gargouri et al., 2012; Piwowar et al., 2018; Suber, 2012). The majority of gold OA journals, do not require the author to pay for publication. For example, 12,647 out of 18,300 (69.1%) journals indexed in the Directory of Open Access Journals (DOAJ, 2022) do not charge APCs and are, therefore, diamond OA. However, most OA articles are published in gold OA journals that do charge authors a fee for publication (Crawford, 2019). APCs were first introduced around 2002 as a business model by OA publishers such as BioMed Central (BMC) and Public Library of Science (PLOS) (Pinfield et al., 2016). The pricing of APCs can vary widely depending on academic discipline and publisher location. For gold OA journals that do rely on APCs, the average author fees range from US$1,371[1] to $2,000 (Crawford, 2022; Jahn & Tullney, 2016; Morrison et al., 2021a; Solomon & Björk, 2016). The variance in these amounts is due to each study's methodological approach and data sources. For example, Jahn and Tullney's (2016) analysis of APCs spent by German institutions used data from the OpenAPC Initiative, which relies on self-reported fees, whereas Solomon and Björk's (2016) study triangulated data from WoS, APC list prices collected by Morrison et al. (2014), and manually collected APCs from journal websites to estimate the amount of APCs paid by authors at four large research institutions in Canada and the United States. Another thing to consider is the unit of analysis of the study. As illustrated by Siler and Franken (2020), results will strongly differ when using journals as the unit of analysis (i.e., calculating one APC per journal) compared to individual papers (i.e., one APC per paper).

[1] All fees in this study will be represented in USD.

The first hybrid journals—subscription journals where individual articles are made freely available through APCs—were introduced a few years after the APC-based gold model (Pinfield et al., 2016) and tend to be considerably more expensive than their gold OA counterparts (Jahn & Tullney, 2016; Laakso & Björk, 2016; Pinfield et al., 2016; Schönfelder, 2020; Solomon & Björk, 2016). Originally suggested as a transitional phase to flip subscription journals to OA (Björk, 2012; Draux et al., 2018; Prosser, 2003), this model has been around for almost 20 years. Large publishers offer hybrid options for most of their journals and market it as their solution to OA (Springer-Nature, 2020; Wiley, 2019). Hybrid OA has been criticized by the scientific community for its high APCs, as well as the potential for publishers to double-dip—charging twice for the same article, in the form of APCs and subscriptions (Eve, 2014; Matthias, 2018; Pinfield et al., 2016; Suber, 2012). Elsevier responded to this criticism by stating that they keep the revenue streams for subscriptions and OA fees separate, arguing that the customer is not charged twice for the same article (Elsevier, n.d.; Lowe, 2019). Previous studies have shown that the average APC for hybrid journals is around $3,000 (Björk & Solomon, 2014; Shamash, 2016; Solomon & Björk, 2016). Björk and Solomon (2015) noted that the trend for the $3,000 price point was set when Springer launched their OpenChoice program in 2004 and was later adopted by most large commercial publishers.

In the context of changing funder requirements, the number of OA, particularly gold and hybrid publications, continues to grow. Using WoS, Crossref and Unpaywall, Piwowar et al. (2018) estimated that between 3.2% and 14.3% of scholarly articles published between 2009-2015 were published in gold OA journals. A recent analysis of gold OA articles in DOAJ-indexed journals indicated a 15.5% increase from 2020 to 2021 alone (Crawford, 2022). Laakso and Björk (2016) tracked the uptake of hybrid articles between 2007 and 2013 and found growth from 666 to 13,994 articles, with the number of articles doubling almost every year. More recently, Jahn, Matthias, and Laakso (2022) found that between 2015 and 2019, Elsevier's hybrid OA articles doubled each year and that the share of OA relative to closed grew from 2.6% to 3.7%.

Publishers appear to be leveraging the growth in the OA market to shift business strategies from traditional subscriptions to OA, coinciding with global developments like Plan S and the increase in funder OA mandates and policies. Coalition S, a consortium of mostly European funders which

has put in place Plan S in 2021, does not support hybrid publishing and limits the APC of gold journals (cOAlition S, 2021), while encouraging subscription and hybrid journals to transition to become fully OA. Plan S and the general increase in OA mandates from funders worldwide have and will continue to affect the publishers' portfolios and business strategies. For example, publishers have begun to create so-called transformative agreements, contractual agreements between institutions (i.e., libraries or consortia) and publishers, including "read-and-publish" and "publish-and-read" models (Hinchliffe, 2019). The majority of transformative agreements are with large publishers since the negotiations and the implementation of those deals require large investments (Hinchliffe, 2020). For example, Projekt DEAL is a German consortium that agreed to transformative agreements with Springer-Nature and Wiley (Projekt DEAL, 2020). As the agreement excluded prestigious *Nature* titles, the German Max Planck Society agreed to a Plan S-compliant deal with Springer-Nature to pay an APC of $11,200 per article to publish OA in and gain access to 34 journals and 21 Nature Review titles (Noorden, 2020).

2.2 Publishing Market

Larivière et al. (2015) found that Elsevier, Wiley-Blackwell, Springer (before the merger with Nature in 2015), and Taylor & Francis publish more than half of the scholarly journal literature indexed in WoS. Based on the number of active, refereed, academic journals indexed in *Ulrichsweb* (N=86,110 as of October 27, 2020), the largest publishers are Elsevier (n=5,158), Springer-Nature (n=4,574), Taylor & Francis (n=4,472), Wiley (n=3,266), and Sage (n=2,292). Traditionally, these publishers heavily relied on subscription revenue, where individual libraries or consortia pay for access to published content for their readers, with university libraries accounting for 68 to 75% of total revenue (Haigh, 2016; Ware & Mabe, 2012). According to the Canadian Association of Research Libraries (CARL), the subscription costs for their 29 member libraries increased by 5 to 7% per year (2011-2015), or approximately 25% over four years (Haigh, 2016). As a consequence of these unsustainable increases, libraries have struggled to maintain their collections and to ensure continued access to scholarly journals (SPARC, n.d.). When numerous research funders and institutions implemented OA policies (ROARMAP, 2022) and libraries cancelled Big Deals and subscriptions because the costs had outpaced their budgets (Shu et al., 2018; UCSF Library, 2020), many publishers created OA revenue options as part of their publishing portfolio

Commercial publishers continue to dominate the publishing market and are increasingly expanding their OA portfolios (Morrison, 2018; Rodrigues et al., 2020). Among gold OA journals with the DOAJ seal—journals that adhere to best practices in OA publishing—four publishers (BMC, Hindawi, MDPI & Springer Open) controlled almost two-thirds of all OA output (Rodrigues et al., 2020), a market concentration more pronounced than the one described by Larivière et al. (2015). Since BMC and Springer Open are both part of Springer-Nature, Rodrigues et al.'s (2020) results underline Springer-Nature's dominant position in the OA publishing market. This market concentration also affects price setting, with dominant players determining fees and profit in the OA market. Studies show just how lucrative the scholarly publishing market is. In 2020, the global scholarly publishing market was valued at $26.5 billion, with $9.5 billion (36%) spent on scholarly journals. Pollock and Michael (2021) estimated that the OA market accounts for $975 million during the same year. The academic publishing market, and OA, are forecast to grow further in the coming years.

Simard et al. (2021) estimated that APCs paid to Elsevier, Wiley, Sage, and Taylor & Francis by Canadian Universities went from $2.2 million in 2015 to $3.2 million in 2019, representing 5.7% of the $295.5 million spent on scholarly publishing in the same period. Studies also indicate that publishers with higher revenues tend to charge higher APCs (Pinfield et al., 2016; Solomon & Björk, 2012). Looking at four large OA publishers (BMC, Frontiers, MDPI, and Hindawi), Khoo (2019) concluded that authors are not price sensitive as APC increases led to increases in article volume. Furthermore, Khoo's (2019) study also suggests that potential economies of scale do not translate into reduced fees but more likely into increased profits.

A recent study by Zhang et al. (2022) analyzed the trend toward "paying to perform research" (p. 7653) in six different countries between 2015 and 2020, estimating the APCs for each year using the latest available APC numbers from the DOAJ and publishers' and journals' websites. They estimated that the global revenues from APCs among twelve major OA publishers exceeded $2 billion in 2022. Zhang et al.'s (2022) study was limited by geographical borders and top OA publishers, while ours examines the five corporations that dominate the academic publishing market.

3. Materials and Methods

This study combines data from WoS, Unpaywall, open datasets of APC list prices (Matthias, 2020; Morrison et al., 2021a), as well as historical annual fees manually retrieved via the Internet Archive Wayback Machine.

3.1 Publications

Peer-reviewed publications published by Elsevier, Sage, Springer-Nature, Taylor & Francis, Wiley between 2015 and 2018 were identified using WoS. Document types were restricted to articles and reviews, as these include original research findings and other document types are often exempt from APCs. Publications were further restricted to include only those with a Digital Object Identifier (DOI) to retrieve their OA status via Unpaywall. In order to identify all journal articles controlled by the five big publishers considered in our study, imprints and/or subsidiary publishing companies were manually assigned to the parent company. For example, journals published by Cell Press were assigned to Elsevier, those published by Palgrave Macmillan to Springer-Nature and those published by Holcomb Hathaway to Taylor & Francis. A total of 136 imprint publishers were assigned to one of the five publishers.

3.2 OA status

We began data collection using an April 2020 snapshot of the Unpaywall database to obtain the OA status (gold, hybrid, bronze, green, closed) for each DOI in our dataset. This paper focuses on hybrid and gold articles only, as they are the ones potentially associated with APC charges. We excluded bronze articles, as it is still unclear whether these articles represent full and permanent OA, as they lack a clear Creative Commons license that would allow reuse and includes articles that publishers may only make free to read for a limited amount of time (Costello, 2019; Piwowar et al., 2018). We therefore assumed that no APCs were paid for bronze articles and excluded these from our study. Combining data from WoS and Unpaywall, we identified the number of hybrid and gold OA articles per journal and year. We later updated the OA status information using a March 2022 snapshot of Unpaywall. We noted a significant decrease in the number of hybrid publications, particularly for Elsevier, and thus lower overall APC revenues than we reported in preliminary findings (Butler et al., 2022b; Haustein & Butler, 2022). A private conversation with

Jason Priem at OurResearch confirmed that Unpaywall's algorithm to distinguish between hybrid and bronze OA improved between these snapshots, particularly for Elsevier, which uses its own license for bronze articles, which initially led to a false classification of bronze as hybrid articles. Therefore, we assume that the algorithms Unpaywall uses to determine OA status, particularly the differentiation between hybrid and bronze, has improved between April 2020 and March 2022 and that the more recent data is more accurate. For an analysis of changes in Unpaywall statuses over time see Sanford (2022).

3.3 Journals and article processing charges (APCs)

We identified APC list prices for each combination of journal and publication year with at least one gold or hybrid article. Due to annual increases, it was important to identify the APC per publication year and not use current fees for articles published between 2015 and 2018 whenever possible. For example, in 2015, Wiley charged an APC of $3,000 for publishing a hybrid article in the journal *Developmental Science*, while the current (April 2023) fee is $4,020. Using the current APC would overestimate the fees paid in 2015 by 34%. Although current APCs are much easier to retrieve from journal websites and/or price lists released by publishers, we argue that such an approach could result in overestimating the actual fees, as done by Zhang et al. (2022).

We first used an open data set (Matthias, 2020) created in April 2020, which includes annual list prices for Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley to provide an overview of their OA journal portfolios over time. The dataset is based on several data sources, including subscription and APC price lists, gold and hybrid OA title lists, and historical website snapshots of the publisher's website that were manually collected through the Internet Archive's Wayback Machine. The dataset includes ISSNs, journal name, publisher, publication year, APC and currency for 95,792 journal-year combinations, 60,788 of which with APC information. Matching via journal title or ISSN in combination with publication year, we were able to retrieve 17,291 (91.7%) of 18,846 journal-year combinations from Matthias (2020). To retrieve additional APCs for gold journals, we used another open dataset by Morrison (2021), which provides annual APCs and metadata (e.g., journal title, print and e-ISSN, publisher) for journals listed in the DOAJ (Morrison et al., 2021b, 2022). These APCs are based on a previous dataset from DOAJ, Crawford (2019), OpenAPC and Morrison (2019), including frequent manual checks on journal websites.

Matching via journal title, ISSN or eISSN in combination with publication year, we were able to retrieve 1,333 (7.1%) journal-year combinations from Morrison (2021).

For journals missing APCs, we manually searched for historical list prices using the Internet Archive Wayback Machine (https://archive.org/web/) to access historical snapshots of journal websites maintained by the publisher and/or academic societies that were affiliated with the journal. We attempted this time-consuming and complex approach for over 700 journal-year combinations, 320 of which were removed from the dataset because the search revealed that the journal did not offer an OA option at the time of publishing (n=106), was only later acquired by one of the large publishers (n=203) or was a book or conference proceedings rather than a journal (n=11). APCs for 482 journal-year combinations were successfully obtained via Wayback Machine and used in this dataset. For the remaining journal-year combinations missing a fee, we applied APCs from a year for which we did have data. In an attempt to under- rather than overestimate fees paid, we prioritized older data from Matthias (2020). We applied APCs using older data from Matthias (2020) in 398 cases (Table 2: “Matthias older”) and older data from a website snapshot via Internet Wayback Machine for 4 journal-year combinations ("IWM older”). For journals without any older APCs, we applied more recent APCs from Matthias (“Matthias newer,” n=371), Morrison (“Morrison newer,” n=40) and Wayback Machine (“IWM newer,” n=4). For 88 (0.5%) journal-year combinations, we had to use current APCs from publisher websites due to a lack of information from other data sources.

Our final dataset contains APC information for 18,846 journal-year combinations, for 1,301 (6.9%) of which we had data from more than one source. For 408 of these, both sources report the exact same fees. For 893 journal-year combinations, APCs differed. These differences might partially be due to conversion between currencies and partially due to erroneous APCs in either the Matthias or Morrison datasets, emphasizing the challenges of gathering accurate historical APC prices. Since our manual check suggested that both data sources were correct some of the time, we chose not to prioritize one source over the other and to use the lower APC amount in case of conflicts. This way, we were more likely to under- rather than overestimate the actual fees paid. An exception was actual APCs obtained through Internet Wayback Machine, which was assumed to be the most reliable data source (n=23). The total estimate we use in this analysis is 7.3% lower

($1.061 billion) than the APC total based on the higher fees ($1.138 billion), with differences per publisher (Table 1). This difference only applies to gold APCs because we do not have more than one data source for hybrid fees, which partially explains the differences between publishers (i.e., those with larger amounts of gold APCs show higher differences).

Table 1. Difference between lower and upper estimate of total APC revenue (in USD) per publisher based on differing APC information for 933 journal-year combinations for gold OA. The lower estimate was used as the basis for this study.

Publisher	Lower estimate	Upper estimate	Difference	Difference %
Elsevier	$221,441,616	$230,750,669	$9,309,054	4.2%
Sage	$31,576,202	$32,660,019	$1,083817	3.4%
Springer-Nature	$589,674,3808	$648,463,842	$58,789,463	10.0%
Taylor & Francis	$76,765,557	$85,135,828	$8,370,271	10.9%
Wiley	$141,316,332	$141,460,621	$144,289	0.1%
All publishers	**$1,060,774,086**	**$1,138,470,980**	**$77,696,894**	**7.3%**

The exact number of journal-year combinations for which APCs were obtained through different methods is shown in Table 2 below. The OA revenues were determined by multiplying the lower APC list price for a particular journal-year combination with the number of gold or hybrid OA articles published that year as determined by Unpaywall. Note that exemptions from APCs and discounts are not considered in calculating our estimates, as we do not have access to this information. The lack of discount and waiver information might lead to overestimating the total APCs paid to publishers. Zhang et al. (2022) similarly encounter this limitation in their study, noting that waiver and discount information remains with the institution and the invoicing publisher.

When analyzing fees on the country level, publications and APCs were fractionalized according to participating co-authors and their affiliations, as information on who paid the APC is unknown. If, for example, a paper with an APC of $2,000 was published by an author from Canada and one from China, 0.5 publications and $1,000 was allocated to both countries. Similarly, when analyzing disciplines using the OECD Fields of Science (FoS) classification system, publications and fees were fractionalized if a journal was classified in more than one FoS class.

Table 2. APC data sources for journal-year combinations used for the analysis. "Actual" indicates that data for the particular year was available, "older"/ "newer" indicates that an APC from the closest available previous or following years was used.

Data source	Number of journal-year combinations	%
Matthias (2020)	**17,291**	**91.7%**
Matthias: actual	16,221	86.1%
Matthias: newer	369	2.0%
Matthias: older	369	2.0%
Matthias: actual | Morrison: actual	303	1.6%
Matthias: older | Morrison: actual	27	0.1%
Matthias: newer | Morrison: newer	2	0.0%
Morrison (2021)	**1,358**	**7.2%**
Morrison: actual	946	4.9%
Matthias: actual | Morrison: actual	303	1.6%
Morrison: newer	38	0.2%
IWM: actual | Morrison: actual	38	0.2%
Matthias: older | Morrison: actual	27	0.1%
Matthias: newer | Morrison: newer	2	0.0%
website: current | Morrison: actual	2	0.0%
Morrison: older	1	0.0%
IWM: older | Morrison: actual	1	0.0%
Internet Wayback Machine	**482**	**2.5%**
IWM: actual	436	2.3%
IWM: actual | Morrison: actual	38	0.2%
IWM: newer	4	0.0%
IWM: older	3	0.0%
IWM: older | Morrison: actual	1	0.0%
Current website	**88**	**0.5%**
website: current	86	0.5%
website: current | Morrison: actual	2	0.0%
All journal-year combinations	**18,846**	**100.0%**

3.4 Limitations

There are several limitations to this study. The first owing to our selection of WoS to retrieve publication outputs. Studies have shown that WoS is limited in its coverage of non-STEM fields and non-English journals (Basson et al., 2022; Mongeon & Paul-Hus, 2016; Zhu & Liu, 2020). Additionally, our study may have missed articles published in new journals, as these need to establish prestige before being indexed in WoS. Since OA is a recent phenomenon, with many new OA journals being published, it may take years before they are indexed. Finally, we did not have access to WoS' Emerging Sources Citation index (ESC), which includes a higher share of OA journals.

We rely on Unpaywall's classification of each article's OA status. As Unpaywall continually updates and improves its algorithm, it may reclassify an article's OA status (Sanford, 2022). Sanford (2022) has found that closed and gold articles are more stable than hybrid, green and bronze. The use of Unpaywall is, therefore, a snapshot of OA status at the time of study.

In our method, we note that we provide an *estimate* of APC spent rather than a *calculation*, as we cannot account for discounts or waivers. Previous studies similarly note the challenge of capturing the actual amount spent owing to vouchers, institutional discounts, or prepayments (Pinfield et al., 2016; Shamash, 2016; Zhang et al., 2022). However, our method rigorously ensures we under- rather than over-estimate APCs by applying historical list prices per journal-year combination.

4. Results

4.1 APCs per publisher

Based on APC list prices and OA status, we estimate that the scientific community paid the five big academic publishers included in our analysis $1.06 billion in OA publication fees, $612.5 million for gold, and $448.3 million for hybrid OA, for a total of 505,903 articles published in 6,252 journals between 2015 and 2018.

The number of OA articles and APCs increased annually over the four-year period from $201.5 million for 91,375 articles in 2015 to $335.4 million for 153,746 articles in 2018 (Figure 1). According to our estimate, the largest amount of OA fees was obtained by Springer-Nature ($589.7 million), followed by Elsevier ($221.4 million), Wiley ($114.3 million), Taylor & Francis ($76.8 million), and Sage ($31.6 million). Of the OA articles analyzed, 69.5% of articles were gold and 30.5% were hybrid, with a slight increase in hybrid articles from 29.0% in 2015 to 32.4% in 2018.

Our results show that in terms of article volume across the four years studied, OA outputs grew by 68.3% (60.1% for gold and 88.3% for hybrid). For gold articles, we see the largest rate of growth occurring from 2015 to 2016 (26.2%), whereas there was only small growth from 2017 to 2018 (3%). For hybrid articles, growth from 2015 to 2016 was even more pronounced at 35.2% and remained fairly stable from 2016 to 2017 (18.2%) and 2017 to 2018 (17.9%). The number of

publications varies between the five publishers we studied, demonstrating different levels of market control and strategies.

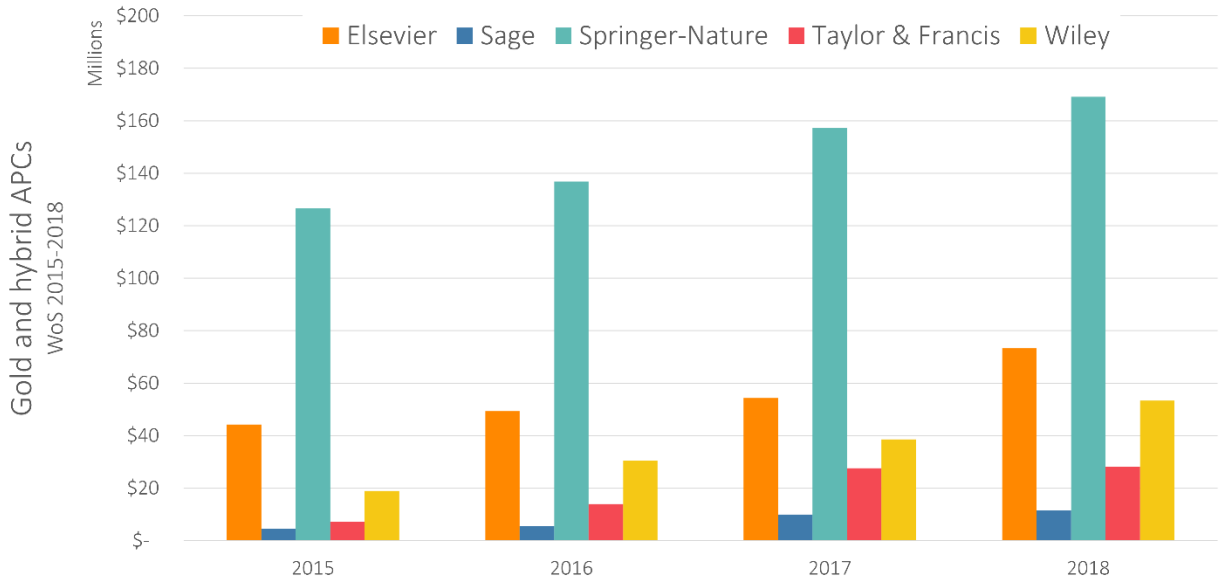

Figure 1. Total amount of gold and hybrid APCs per publisher per year.

Figure 2 displays the share of total estimated APC revenues generated with gold and hybrid OA for each publisher. It is interesting to note that publishers seemed to follow different OA strategies in both the number of publications and APCs obtained: Springer-Nature (82.7% articles gold; 75.0% APCs from gold), Sage (82.1%; 71.0%) and Taylor & Francis (75.8%; 66.0%) clearly focused on gold OA, while Elsevier (60.1% articles hybrid; 79.4% APCs from hybrid) and Wiley (53.9%; 63.4%) drew more revenue from publishing hybrid OA articles in journals for which they already received subscription fees.

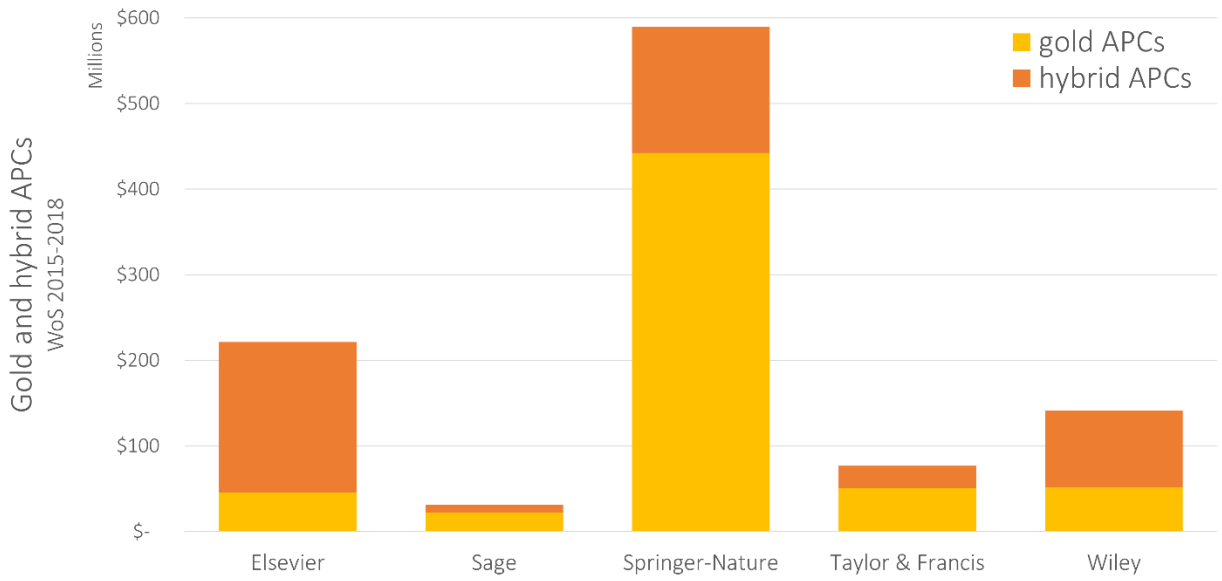

Figure 2. Total amount of gold and hybrid APCs per publisher.

Despite only 30.5% of OA articles being hybrid over the four years analyzed, hybrid APCs make up 42.3% of total APCs. The publishers obtained a total of $612.5 million for gold and $448.3 million for hybrid articles published between 2015 and 2018. The publishers' different OA portfolios, described above in terms of the number of gold and hybrid articles, are also reflected in their APCs obtained. Springer-Nature received $442.1 million from gold and $147.6 million from hybrid APCs, while Elsevier obtained $175.9 million in hybrid APCs and $45.6 million in gold APCs (Figure 2). Wiley received $51.7 and $89.6 million, Taylor & Francis $50.7 and $26.1 million and Sage $22.4 and $9.2 million in gold and hybrid APCs, respectively.

It should be noted that more than half (53.1%) of Elsevier's 43,080 gold OA articles had an APC of $0. These OA articles without APCs are not captured in Figure 2 but are listed separately in Table 3. The overall share of OA articles with an APC=$0 for all publishers was 12.4% (Table 3). This represents 43,623 of 351,559 gold OA articles, for which authors did not have to pay an APC. Elsevier published the largest number of OA articles without APCs (n=22,888; 53.1% of the publisher's gold OA articles), followed by Springer (16,957; 7.0%), Taylor & Francis (2,717; 9.8%), Sage (619; 4.2%) and Wiley (442; 1.9%). The overall share of gold OA articles without compared to those with APCs increased from 9.9% in 2015 to 13.6% in 2017 and then decreased again in 2018 to 12.0%.

Table 3. Number and share of gold articles without APCs per publisher per year. Percentages are based on the share of gold OA articles with APC=$0 compared to all gold OA articles per publisher per year.

	2015		**2016**		**2017**		**2018**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Elsevier	2,208	31.7%	6,440	62.6%	7,726	61.8%	6,514	48.9%	22,888	53.1%
Sage	92	4.6%	81	3.0%	271	5.7%	175	3.2%	619	4.2%
Springer-Nature	3,748	7.5%	4,004	6.6%	4,520	6.7%	4,685	7.2%	16,957	7.0%
Taylor & Francis	223	9.5%	388	9.3%	1,116	11.6%	990	8.5%	2,717	9.8%
Wiley	136	4.0%	43	1.0%	128	2.0%	135	1.6%	442	1.9%
All publishers	**6,407**	**9.9%**	**10,956**	**13.4%**	**13,761**	**13.6%**	**12,499**	**12.0%**	**43,623**	**12.4%**

Average APCs based on articles published were $1,989 for gold OA (excluding articles without APCs) and $2,905 for hybrid OA. On average, hybrid APCs were thus 46.0% more expensive than their gold counterparts. Wiley had the highest APCs, with an average of $2,297 for gold OA articles and $3,343 for hybrid articles. At $1,571, Sage had the lowest gold fees, and Elsevier had the lowest hybrid APCs ($2,715). As shown in Table 4, most hybrid APCs increased over the years, while gold APCs mostly decreased or stayed the same.

Table 4. Average gold and hybrid APCs per publisher per year.

	Publisher	2015	2016	2017	2018	2015-2018
Gold (APCs>$0)	Elsevier	$2,461	$2,259	$1,756	$2,463	$2,256
	Sage	$1,977	$1,534	$1,588	$1,428	$1,571
	Springer-Nature	$2,181	$1,813	$1,866	$2,013	$1,957
	Taylor & Francis	$2,644	$2,019	$1,948	$1,964	$2,025
	Wiley	$2,241	$2,237	$2,274	$2,368	$2,297
	All publishers gold APCs	*$2,217*	*$1,864*	*$1,884*	*$2,040*	*$1,989*
Hybrid	Elsevier	$2,458	$2,737	$2,742	$2,848	$2,715
	Sage	$2,900	$2,860	$2,712	$2,857	$2,815
	Springer-Nature	$2,897	$2,877	$2,901	$2,963	$2,914
	Taylor & Francis	$2,914	$2,926	$2,942	$2,948	$2,938
	Wiley	$3,156	$3,367	$3,424	$3,341	$3,343
	All publishers hybrid APCs	*$2,713*	*$2,906*	*$2,924*	*$2,989*	*$2,905*

4.2 APCs per journal

Analyzing amounts of APCs at the journal level, the highest totals were obtained by two Springer-Nature gold OA journals. Over the four-year period analyzed, we estimate that *Scientific Reports* obtained $105.1 million and *Nature Communications* $71.1 million in APCs. As shown in Figure 3, those two journals generated by far the highest amount of APCs, which can be explained by the large number of articles published. *Scientific Reports* published 73,206 and *Nature Communications* 16,122 articles between 2015 and 2018, respectively, while the journal with the third largest APC amount, *Cell Reports* ($10.3 million), published only 4,211 OA articles during the same period. Among the top 50 journals based on total APCs (Figure 3), all but eight were gold OA journals (84.0%), which can again be explained by the fact that all articles published in gold OA journals are subject to APCs, while only a fraction of authors in hybrid journals choose to pay for OA. Among the top 50 journals by the total amount of APCs, the majority (58.0%) was published by Springer-Nature.

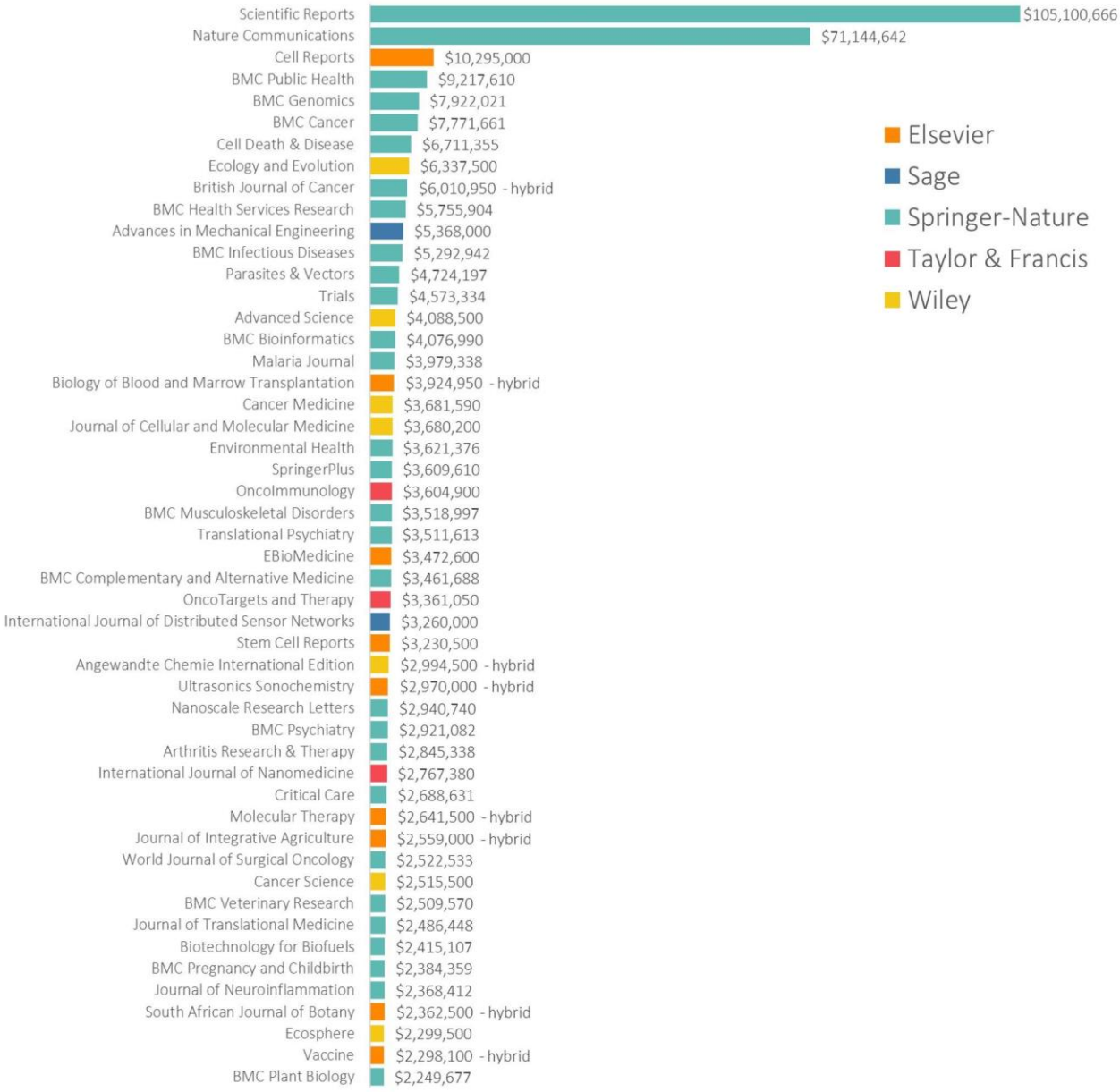

Figure 3. Top 50 journals by total amount of APCs 2015-2018. Hybrid journals are labeled, all others are gold.

When looking at the average APC per article (Figure 4), three Springer-Nature gold journals had the most expensive fees: *Diabetes Therapy* ($5,478), *Infectious Diseases and Therapy* ($5,295) and *Rheumatology and Therapy* ($5,169). However, these were closely followed by a range of hybrid Elsevier and Wiley journals with APCs of or around $5,000. Reflecting the higher APCs of hybrid compared to gold OA journals, 86.0% of the 50 most expensive APC journals were

hybrid. Twenty-nine (58.0%) of the most expensive journals according to average APC were published by Elsevier, all except one were hybrid, reflecting the publisher's OA portfolio described in section 4.1.

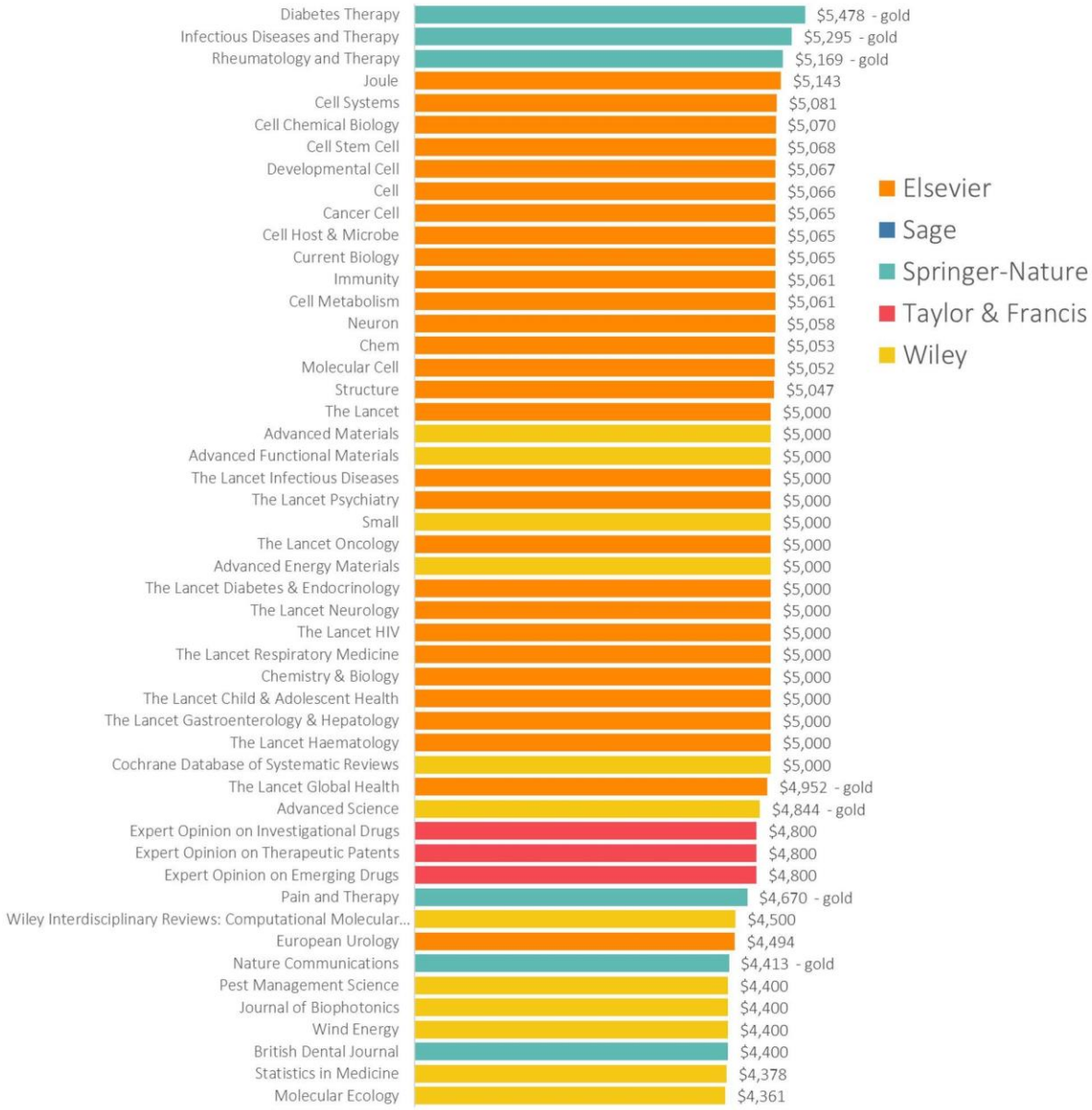

Figure 4. Top 50 journals by average APCs 2015-2018. Gold journals are labeled, all others are hybrid.

4.3 APCs per country.

Figure 5 displays the total fractionalized expenditures per country for the 25 countries with the largest amounts of APCs. According to our estimates, the US ($184.7 million), China ($148.0 million) and the UK ($134.6 million) are responsible for paying the largest amounts of OA fees to the publishers. Some countries pay a larger share of hybrid APCs than expected. For example, Poland (82.9% of APCs, 71.5% of OA articles hybrid), Austria (76.1%, 66.2%), the Netherlands (75.4%, 65.8%), the UK (73.4%, 63.8%) followed by Sweden (62.2%, 51.1%), Brazil (53.4%, 38.4%), Norway (52.7%, 40.6%) and Finland (52.2%, 40.3%) pay more APCs for hybrid than for gold publications. For comparison, the expected rates for the entire dataset would be 42.3% of APCs and 30.5% of OA publications to be hybrid. On the other end of the spectrum, among the top 25 countries shown in Figure 5, Taiwan (85.8% of APCs, 91.7% of OA articles gold), South Korea (85.0%, 90.0%) and China (83.7%, 88.2%) pay and publish more gold OA articles than expected.

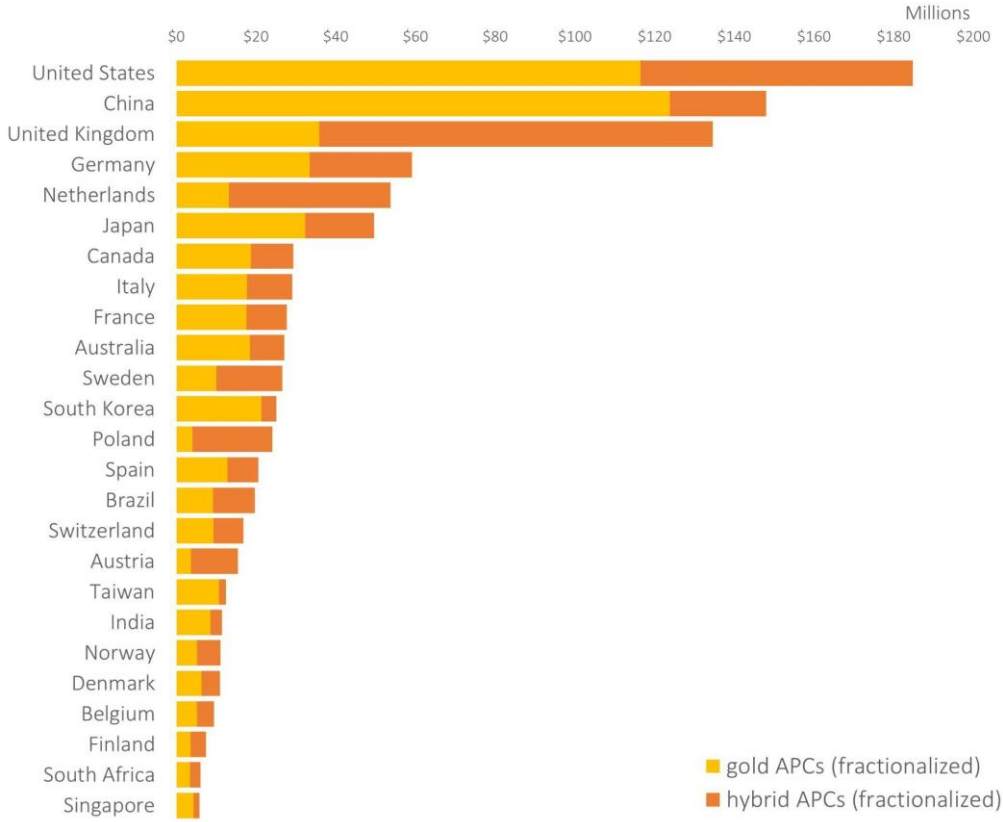

Figure 5. Top 25 countries by total amount of APCs expenditures 2015-2018 based on fractionalized publications.

4.4 APCs per discipline

When analyzing the APC estimates per discipline (Figure 6), the majority of fees can be allocated to journals from either the Natural Sciences ($450.5 million) or the Medical and Health Sciences ($423.1 million). Together these two disciplines make up 82.7% of the global estimate of APCs paid during the four-year period analyzed. APCs paid to publish in Humanities journals make up the smallest amount of $8.3 million, which may be explained by poor indexation of journals in WoS, the publishers' disciplinary portfolios, and the importance of books rather than journal publications. Interestingly, the Humanities and the Social Sciences pay the great majority of OA fees for hybrid OA, accounting for 89.9% and 85.1% of their OA fees, respectively. In the Natural Sciences, authors spent 65.5% of OA APCs on publications in gold journals.

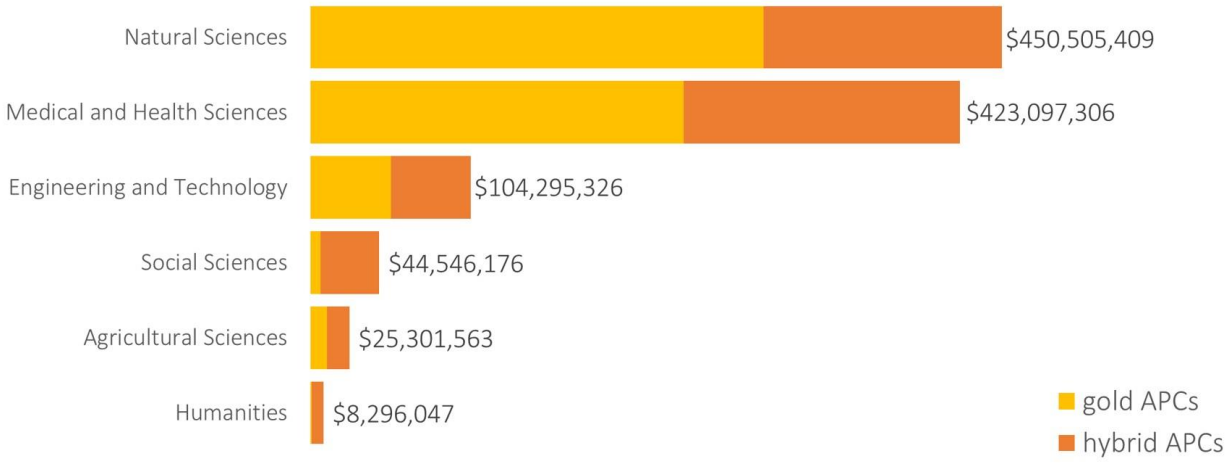

Figure 6. Total amount of APCs for gold and hybrid publications (n=505,555) per OECD Field of Science. APCs of journals classified in more than one OECD FoS were fractionalized.

Figure 7 shows the share of publications per OA status per discipline, reflecting the high share of hybrid articles in the Humanities and Social Sciences described in the previous paragraph. It also shows the share of OA articles published in gold OA journals that do not require the author to pay (APC=$0). Our data shows that among the five big publishers, these gold journals without APCs are more popular in Engineering and Technology (11.2%) as well as Natural Sciences (11.2%) but not very common in the Humanities (3.3%) and Medical and Health Sciences (5.2%).

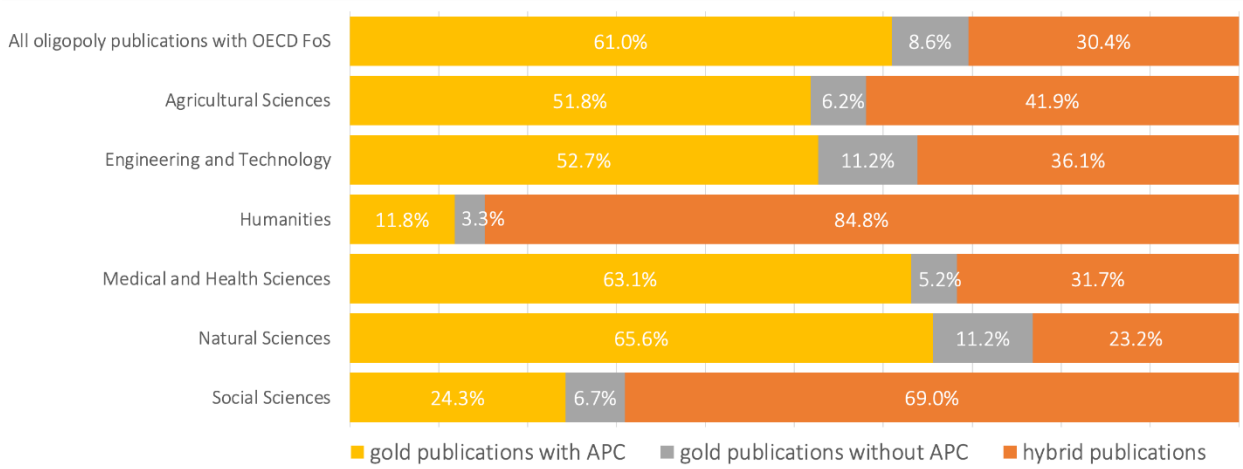

Figure 7. Share of gold publications with and without APC and hybrid publications (n=505,555) per OECD Field of Science.

5. Discussion

Our analysis of number of gold and hybrid publications and estimates of APCs charged by five publishers (Elsevier, Sage, Springer-Nature, Taylor and Francis, Wiley) illustrate the continued growth in the OA market. Although OA was meant to provide free and unrestricted access to research, publishers have found a new revenue stream by equating OA with APCs, thereby creating an economic barrier.

We estimate that the five publishers included in our study generated $1.06 billion in revenues from gold and hybrid APCs from 2015-2018. Our results highlight that APCs have become a considerable source of revenue in addition to the traditional business model of subscription fees paid by academic libraries. It should be emphasized that by limiting the analysis to five publishing companies and WoS-indexed journals, the $1.06 billion estimate represents only a fraction of the total market for gold and hybrid OA. By focusing on Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley, we did not include various OA mega-journals and publishers such as PLOS, MDPI, and Frontiers, which have been identified to be major players in the OA publishing landscape (Khoo, 2019; Zhang et al., 2022).

Our data indicates that on average the five publishers charged $1,989 for gold and $2,905 for hybrid articles between 2015 and 2018. The Fair Open Access Alliance (FOAA), an organization that evaluates sustainable OA publishing, analyzed the cost to publish OA and demonstrated that

much lower APCs of no more than $50 per page are feasible to sustain an OA journal. FOAA advocates for transparency in APC prices and recommends that author fees should not exceed $1,000 per article (FOAA, 2022). Factoring in differences between journals' rejection rates, staffing, editorial services and publishing volume, Grossman and Brembs (2021) similarly estimated that fees between $200 and $1,000 per article are sufficient to sustain a gold OA journal. They calculate that an APC of $500 could still accommodate a 10% profit margin (Grossmann & Brembs, 2021). Rodrigues et al. (2020) found that 59% of gold journals indexed in DOAJ charge APCs less than $1,000, demonstrating the possibility of this average price point when generating profit is not the main purpose.

Breaking down average pricing for gold and hybrid and per publisher demonstrates how APCs influence the publisher's overall revenue. For example, Crawford's (2021) analysis of journals in the DOAJ shows that although Wiley publishes fewer gold articles, they draw more revenue than Elsevier due to higher APCs. In addition, previous studies (Budzinski et al., 2020; Solomon & Björk, 2016) indicate that higher publication volume correlates with higher APC pricing, which suggests that traditional commercial publishers can dictate pricing once they exert their dominance in the OA market, especially since authors display a lack of sensitivity to the high pricing (Khoo, 2019; Morrison, 2021). Reputation seems to be the commodity that drives researchers to select a certain journal, and publishers set their APC fee accordingly (Budzinski et al., 2020). Schönfelder (2020) found a correlation between APCs and the journal's impact, but more so for gold than hybrid journals, where APCs are essentially "mirroring the citation impact in open-access journals" (p. 24-25). It is precisely because of this intertwining of the publisher's prestige and reputation with profit that commercial publishers have managed to equate OA with APCs, excluding many authors from publishing.

Our findings show that Springer-Nature leads in terms of both overall OA article volume and total APCs with a clear focus on generating revenue from gold OA, corroborating previous studies (Crawford, 2021; Rodrigues et al., 2020; Zhang et al., 2022). Rodrigues et al. (2020) found that Springer-Nature publishes 35% of journals in DOAJ, which represents an even larger share than what they control in the traditional publishing market. Springer-Nature's dominance in the gold OA market can partially be attributed to their strategy to focus on acquiring well-established OA

publishers and journals, but also a large volume of new journal titles (Rodrigues et al, 2020). For example, between 1992 and 2020, 34 *Nature* derivatives (e.g., *Nature Genetics*, *Nature Ecology and Evolution*) were founded (Khelfaoui & Gingras, 2022), one of which is now the OA journal with the second highest sum of APCs in our dataset. As of 2021, Springer-Nature's flagship journal *Nature* charges a hybrid APC of $11,200 (Noorden, 2020). In 2008, Springer-Nature acquired *BioMed Central (BMC)*, a prominent and large OA publisher with more than 300 journals[2]. Our data shows that Springer-Nature publishes the two gold journals that generate the highest revenues: *Scientific Reports* and *Nature Communications.* Together, these two flagship journals bring in 39.9% of Springer-Nature's $442.1 million gold OA revenues. Khelfaoui and Gingras (2022) describe the system in which rejected manuscripts are transferred from most to least prestigious (and selective) journals in the *Nature* family with *Nature* on top, and the OA journals *Nature Communications* in the middle and *Scientific Reports* on the bottom of the manuscript transfer pyramid. Even though its APCs are higher, Khoo (2019) found that *Scientific Reports* overtook the well-established OA journal PLOS ONE as the largest mega journal in 2017. Despite their focus on gold OA, Springer-Nature also generates $147.6 million from hybrid APCs and demonstrates significant growth with the number of hybrid articles increasing by 83.9% from 2015 to 2018. This suggests that Springer-Nature is likely to maintain and further build on its dominance in the OA market.

Elsevier's OA portfolio has a clear focus on hybrid, with 60.1% of their WoS-indexed OA articles published in hybrid journals, accounting for revenues of $175.9 million. Jahn et al. (2022) found that Elsevier's number of hybrid articles doubled each year, and their share of hybrid articles continues to increase, showing their continued investment in the traditional market, where they yield revenues from both subscriptions and APCs. At $45.6 million, the total estimate for Elsevier's gold APC revenue is comparatively small among publishers, as smaller players like Wiley and Taylor & Francis generate more gold APCs than Elsevier. Elsevier's lower revenue from gold can be explained by the lower amount of gold articles, but also by their large share of OA papers where the APC is reported as $0. Over half of Elsevier's gold OA articles are from journals where the author is not charged an APC, often owing to agreements where universities or

[2] See https://www.biomedcentral.com/about

societies cover the costs of these fees (Morrison, 2017). These articles may be published in journals that follow a diamond OA model or journals that waived APCs as an introductory model to attract authors. Although removing fees for the authors is a more equitable approach to academic publishing, as it excludes neither readers nor authors on economic grounds, it should be noted that commercial publishers maystill generate revenue from this model (Bosman et al., 2021; Khanna et al., 2022). We assume that for-profit publishers invoice academic societies at similar rates for diamond OA journals as they would charge authors APCs for gold OA or libraries for subscription journals. This revenue stream is not reflected in our estimates, because we do not have access to these fees.

Our data shows significant growth for OA articles of any type published by Elsevier between 2015 and 2018: hybrid output increased by 49.9% and gold with APC by 43.1% and diamond by 195.0%. Interestingly, after tripling from 2015 to 2016, the growth in gold OA where APC is reported as $0 slowed down in 2017 and decreased by 15.7% in 2018. Although our study did not focus on investigating the prevalence of diamond OA, we found that 12.4% of gold articles (8.6% of all OA) published by the studied publishers had an APC of $0. At more than half (53.1%) of their gold OA papers published at no cost for the authors, Elsevier's uptake of gold journals without APCs stood out among the five publishers. The other publishers take less advantage of this model. Taylor & Francis published 9.8%, Springer-Nature 7.0%, Sage 4.2% and Wiley 1.9% of their gold OA articles without an APC. With the exception of Elsevier, the uptake of gold journals without author fees remains far below the 43.2% of diamond articles found by Siler and Franken (2020) using the DOAJ. This illustrates that diamond OA is still a phenomenon that is much more common outside of the Western group of large publishers, as the DOAJ is a more inclusive source of data that indexes publications from all over the world.

When it comes to OA output and revenues, Taylor & Francis and Sage are smaller players among the publishers we examined. They account for 7.2% and 3.0% of the $1.06 billion of APC revenue. Studies have shown that new OA-only publishers, such as MDPI and Frontiers, generate more OA publication volume and revenues than some of the big five publishers which dominate the traditional publishing market. However, Wiley recently acquired the large OA publishing house Hindawi, which is already well-established in the OA market (Crawford, 2022). This highlights

continues shifts in the market and future studies should expand the scope of our work to include all major publishers.

6. Conclusion and outlook

OA was initially proposed as a way to make research output available to everyone in order to "accelerate research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge" (BOAI, 2001, para 1). However, this movement conflicts with the profit-driven model of traditional commercial publishing (Logan, 2017), which reaps what Smith (2018) called an obscenely high profit margin. For instance, in 2017, Elsevier made $1.8 million in journal revenue with a 37% profit margin annually, while Springer-Nature earned $1.3 million with a 23% annual profit margin (Aspesi et al., 2019). This high-profit model is founded on the work of academics who generally volunteer their time as authors and reviewers, producing this work to publishers for free (Buranyi, 2017), which has been previously estimated to amount to about 1.9 billion in unpaid labor per year (Logan, 2017).

While OA could theoretically overcome inequities of academic publishing, publishers have used APCs and more recently transformative agreements (Pooley, 2021) to keep their businesses highly profitable. Many consider it problematic that instead of removing author fees, these deals merely push the costs back to the libraries (Borrego et al., 2020). Similar to Big Deals, transformative agreements thus enable publishers to lock in their prices (Poynder, R., 2018). It remains to be seen whether these agreements will successfully transform the academic journal landscape into equitable and sustainable OA publishing or whether they are just another source of revenue for commercial publishers, another perversion of the initial idea of OA. As stated in the BOAI 20th Anniversary Recommendation:

> "When we spend money to publish OA research, remember the goals to which OA is the means. Favor models which benefit all regions of the world, which are controlled by academic-led and nonprofit organizations, which avoid concentrating new OA literature in commercially dominant journals, and which avoid entrenching models in conflict with these goals. Move away from read-and-publish agreements." (*BOAI20*, 2022, para 13).

Instead of making scholarly publishing sustainable and accessible for all, high APCs and transformative agreements aim to preserve the status quo, where academic publishing is a highly profitable business for a few corporations.

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Author contributions

Leigh-Ann Butler: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing—original draft, Writing—review & editing. Lisa Matthias: Conceptualization, Data curation, Methodology, Validation, Writing—review & editing. Marc-André Simard: Data curation, Investigation, Writing—original draft, Writing—review & editing. Philippe Mongeon: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Writing—review & editing. Stefanie Haustein: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing—original draft, Writing—review & editing.

Competing interests

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Data availability

The underlying data is available in Zenodo: https://doi.org/10.5281/zenodo.7086420 (Butler et al., 2022a).

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