

**FUNDING THE BUSINESS OF OPEN ACCESS: A BIBLIOMETRIC ANALYSIS OF
ARTICLE PROCESSING CHARGES, RESEARCH FUNDING AND THE REVENUES
OF THE OLIGOPOLY OF PUBLISHERS**

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Abstract

Since the early 2010s, more than half of peer-reviewed journal articles have been published by the so-called oligopoly of academic publishers - Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley. These publishers are now increasingly charging fees for open access journals, especially given the rise of funder OA mandates. It is worthwhile to examine the amount of revenue generated through OA fees since many of the journals with the most expensive article processing charges are owned by the oligopoly. This study aims to estimate the amount of article processing charges for gold and hybrid open access articles in journals published by the oligopoly of academic publishers, which acknowledge funding from the Canadian Tri-Agencies between 2015 and 2018. The Tri-Agency Open Access Policy on Publications mandates that all funded research for Canadian Institute of Health Research, Natural Sciences and Engineering Research Council, and Social Sciences and Humanities Research Council grantees be made available as OA. To comply, grantees will often use grant funds to pay OA fees, or APCs. During the four-year period analyzed, a total of 6,892 gold and 4,097 hybrid articles that acknowledge Tri-Agency funding were identified, for which the total list prices amount to \$USD 25.3 million (\$13.1 for gold and \$12.2 for hybrid).

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List of Abbreviations

APC: Article processing charge

BMC: BioMed Central

BOAI: Budapest Open Access Initiative

CARL: Canadian Association of Research Libraries

CIHR: Canadian Institutes of Health Research

COKI: Curtin Open Knowledge Initiative

CRC: Canada Research Chair

CRKN: Canadian Research Knowledge Network

DOAJ: Directory of Open Access Journals

DOE: Department of Energy

DOI: Digital object identifier

EC: European Commission

FA: Funding acknowledgement

FOAA: Fair Open Access Alliance

FRQ: Fonds de recherche du Québec

JIF: Journal impact factor

NSF: National Science Foundation

NIH: National Institutes of Health

NSERC: Natural Sciences and Engineering Research Council

OA: Open access

OSM: Open Science Monitor

OSTP: White House Office of Science and Technology

PID: Persistent identifier

PLOS: Public Library of Science

ROARMAP: Registry of Open Access Repositories

SSH: Social sciences and humanities

SSHRC: Social Sciences and Humanities Research Council

STEMM: Science, technical, engineering, mathematics and medicine

TA: Transformative Agreement

TAOAPP: Tri-Agency Open Access Policy on Publications

TIPS: Tri-Agency Institutional Programs Secretariat

UKRI: United Kingdom Research and Innovation

USD: United States Dollar

UT: Web of Science Accession number

WoS: Web of Science

1. INTRODUCTION

The early open access (OA) manifestos – the Budapest Open Access Initiative (BOAI) (2002), the Bethesda Statement on Open Access Publishing (2003), and the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (2003) – carved out the general aims for the OA movement as a way to increase fundamental access to scientific discoveries and findings. Science, as a public good, should be openly available and free from paywalls to enable discovery, disseminate research equitably, and ensure the largest reach and impact of findings. However, the dominance in the scholarly publishing market by a select number of for-profit companies, the so-called oligopoly of academic publishers, impedes OA's advancement. The oligopoly of publishers refers to five publishers (Elsevier, SAGE, Springer-Nature, Taylor & Francis, Wiley) who exert a large amount of power and influence over the market owing to their acquisitions of small publishers and high concentration in the volume of publications (Larivière et al., 2015). The oligopoly's concentrated control over the market creates conditions where they can influence market pricing, inflate prices, and create inequities by excluding authors on financial grounds (Chan et al., 2020; Harle & Warne, 2019; Olejniczak & Wilson, 2020; Siler & Frenken, 2020). Such economic barriers are grounded in a capitalist system that restricts access, for a fee, to more resourced authors, institutions, and countries. Since the five oligopoly publishers—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), fees that authors pay to publish are not justified by the actual costs related to the publication process itself (FOAA, n.d.) and a significant amount leaves the academic community to increase shareholder profits.

1.1 The Rise of Funder OA Policies

As the OA movement gained traction, funders across the globe increasingly mandated that the research stemming from their funds must be made freely available. The first funders to require OA through policy included the National Institutes of Health (NIH) in the US and Wellcome Trust in the UK, followed by other European funders like the European Commission (EC) and eventually leading to Canada with the Tri-Agency Open Access Policy on Publications (TAOAPP) (Kirkman, 2018; Vincent-Lamarre et al., 2016).

As of June 2022, there are approximately 1,113 OA policies or mandates worldwide, of which 85 are specific to funders. The Registry of Open Access Repository Mandates and Policies (ROARMAP), an international registry that charts the growth of OA mandates and policies adopted by universities, research institutions, and research funders, records the significant rise in OA mandates across the globe since 2005, and demonstrates the diversity in the requirements themselves, through features such as immediate OA, embargo periods, or specifying deposit in institutional or disciplinary repositories (ROARMAP, 2022).

As more funders required their grantees to comply with OA policies, publishers found a new business market with article processing charges (APCs). The APC model effectively shifted the paywall from reader (often via libraries) to author, entrenching the author as the payee in the system. Large commercial publishers, who dominate the publishing market, found a new and reliable source of revenue in the OA market through APCs.

Guédon (2019) remarks that many policymakers do not see the progress in OA they hoped to achieve. Nevertheless, recent developments demonstrate the community’s continued advocacy and commitment to fostering an inclusive and equitable system through OA. For example, the BOAI celebrated its 20th anniversary in 2022 and published the BOAI20 – four recommendations that aim to address the systemic problems that impede progress (BOAI20, 2022). Recommendation #3 focuses on problems in publishing and recommends favouring “inclusive publishing and distribution channels that never exclude authors on economic grounds”, encouraging a move away from APCs (BOAI20, 2022, para. 13). Additionally, in November 2021, the United Nations Educational Scientific and Cultural Organization’s (UNESCO) *Recommendations on Open Science* were adopted by the General Conference of UNESCO. The recommendations stress, as a core value, science for the collective benefit and a “global public good” (UNESCO, 2021b, p. 17). Both the BOAI20 (2022) and UNESCO recommendations (2021b) call to question the inequities created through such business approaches as the author-pays model, which commodifies knowledge and privileges the profits of large publishers over the equitable participation of all players in the scientific enterprise.

1.2 Tri-Agency OA Policy on Publications

In 2015, Canada’s three federal granting agencies, The Tri-Agencies – Canadian Institute of Health Research (CIHR), Natural Sciences and Engineering Research Council (NSERC), and Social Sciences and Humanities Research Council (SSHRC) – implemented the Tri-Agency OA Policy on Publications (TAOAPP) (see Appendix A). The policy stipulates that grant holders make their peer-reviewed publication freely available as OA through two routes:

1. Online Repository: in an institutional or disciplinary repository, which can follow a 12-month embargo period.
2. Journals: in a journal that offers immediate OA or on its website within 12 months.

In the first route to compliance, authors can publish their work in any journal (i.e., subscription journal, gold, or hybrid) and then deposit their final, peer-reviewed publication in a disciplinary or institutional repository (Government of Canada, 2016). This route is otherwise known as green OA. Articles deposited as green OA are not the publisher's version of record – the publisher's “typeset, copyedited, and published version” of the article (Crossref, 2020, para 3) – and are further restricted by the journal's copyright policies that often delay the author's ability to immediately deposit a version of the article (Hinchliffe, 2020). Since authors do not pay OA fees when depositing their articles in green routes, this first route of the TAOAPP and model of publishing OA will not be the focus of the proposed study.

The second route in the TAOAPP states that authors can publish in a journal that offers immediate OA (gold), or in a journal that requires subscriptions to read but allows authors to pay a fee - an APC - to make their publication OA (hybrid). To pay these fees, Tri-Agency grant holders can use a portion of their funds toward APCs since publishing costs are considered eligible grant expenses (Government of Canada, 2016). However, these author fees are prohibitively expensive and can use up a large portion of grant funds. For example, the average amount of an NSERC Discovery Grant (Individual) in 2018 was \$29,599 CDN for early career researchers (ECR) and \$40,355 CDN for established researchers (ER) (NSERC, 2020). An ECR researcher would use 10% of a grant to pay a \$3000 APC. This amount could instead fund a research assistant at a Canadian university.

It is beneficial that funding agencies, including the Tri-Agencies, monitor how much researchers direct toward OA fees from their grant funds and analyze the sustainability of these fees, especially in the context of changing publisher models due to developments like Plan S (Crotty, 2021). Such analysis can inform funders of potential unintended consequences of policies, like the economic barrier of high OA fees.

1.3 Problem Statement

Broadly, this study aims to explore the unsustainability and inequities of the dominant APC model for publishing in gold or hybrid OA journals. The growth of OA continues to increase, as do the fees to publish OA. However, the market pricing is not set on typical supply and demand, but instead by what authors are willing to pay, often influenced by journal prestige (Brembs, 2017; Khoo, 2019; Logan, 2017). To pay for these fees, authors often use grant funds, provided by federal funding or institutions.

In Canada, Tri-Agency research grants are funded through the Government of Canada with public tax dollars. Since the TAOAPP allows researchers to use grant funds to pay for APCs (Government of Canada, 2016), public tax dollars are being streamed into the revenues of large commercial publishers. The APC model exacerbates inequities and is an unsustainable model since socio-economic factors, like prestige, influence market pricing that continues to rise past the rate of inflation (Grossmann & Brembs, 2021; Khoo, 2019; Morrison et al., 2022; Olejniczak & Wilson, 2020; Siler & Frenken, 2020).

However, no known study shows how much researchers funded by the Canadian Tri-Agency research grants pay in OA fees (APCs). It is therefore in the best interest of funding agencies (and

taxpayers) to capture data on and monitor the amount of APCs paid by their grant holders to better assess the sustainability of OA and ensure the best use, reach, and impact of funding dollars.

1.4 Research Questions

This study aims to answer the following main research question and associated sub-questions:

RQ: What is the amount of APCs paid for OA (gold and hybrid) articles authored by Canadian researchers which acknowledge Tri-Agencies funding published in an oligopoly journal indexed in the Web of Science between 2015 and 2018?

- a. What is the amount in APCs paid for gold vs hybrid articles?
- b. What is the amount in APCs obtained by the five oligopoly publishers Elsevier, Sage, Springer-Nature, Taylor & Francis, and Wiley?
- c. What is the amount of APCs paid per journal?
- d. How does APC spending differ between CIHR, NSERC and SSHRC and jointly administered grants?

1.5 Significance of Study

This is the first study that estimates how much researchers, who acknowledge Tri-Agency funding, have paid in OA fees (APCs). Results will reveal:

- The impact of grant funds, and the best use of public tax dollars;
- The growth of the APC market in Canada between 2015-2018;
- A greater understanding of financial barriers that may prevent grantees from complying with OA mandates;
- Contribute to bibliometric studies on OA publishing models, and the oligopoly's move toward OA.

It should be noted that parts of this study, which focus on the global amounts of APCs paid to oligopoly publishers, are currently under review at the open access journal *Quantitative Science Studies* and published as a preprint (Butler et al., 2022b). The underlying dataset of the global study is available as open research data (Butler et al., 2022a). Unfortunately, the data used for the thesis which uses Web of Science (WoS) data to extract author addresses as well as funding acknowledgements cannot be published due to copyright restrictions of proprietary Clarivate data.

1.6 Research Design

This study employs quantitative methods to answer the research questions. Specifically, the research design uses bibliometric analysis, a method often utilized in library and information science and scholarly communication (Haustein, 2012; Sugimoto & Larivière, 2018).

Bibliometrics statistically analyzes the units of research outputs, such as journal articles, to gain insights on the patterns and relationships in a given discipline, topic, institution, funder, or country (Fu et al., 2013; Sugimoto & Larivière, 2018).

The bibliometric approach is useful for the current study since the aim is to analyze the corpus of publications, specifically journal articles, for grantees who acknowledge Tri-Agency funding between 2015 – 2018. More specifically, this study does not employ sampling methods as the population of study is all available publication outputs in the Web of Science. Van Leeuwen (2004) explains that bibliometrics assumes that the most important research will eventually be accessible to the scientific community in serial literature, which is limiting to certain fields because of field specific research practices. These limitations are considered in the current study (see Section 3.4).

2. LITERATURE REVIEW

The control over scholarly publishing has moved from the hands of the scientific community who not only produced the science but sought to disseminate this knowledge through their learned societies, to the intermediary publisher who could manage the sharing of this research in print form. The following sections examines scholarly publishing's history from the 17th century to present day 21st century (2.1), the birth of OA (2.2) and its various models (2.3), OA's growth (2.4), the publishing market (2.5), and funder OA policies (2.6).

2.1 The History of Scholarly Publishing and the Rise of Large Commercial Publishers

For over 350 years, publishing has been the means to disseminate scientific findings and knowledge. During the Scientific Revolution, ideas and findings were communicated via letters and managed by learned societies (Fjallbrant, 1997; Harmon & Gross, 2007). These letters soon evolved into a new form called periodicals, or scholarly journals. The first scientific journals - *Journal des Sçavans* and the *Philosophical Transactions of the Royal Society of London* – were first published in 1665 and established a system for sharing knowledge we now understand as scholarly publishing (Fjallbrant, 1997; Greco, 2016; Guédon, 2001; Harmon & Gross, 2007; Kling & Callahan, 2005; Larivière et al., 2015; McCutcheon, 1924). Guédon (2001) explains the different aims of these journals – that the *Philosophical Transactions* recorded original scientific findings, while the outputs of the *Journal des Sçavans* compare to what we now know as scientific journalism. Regardless of their differences, these founding periodicals formalized the dissemination of scientific findings into print form and created the system we now understand as scholarly publishing.

Learned societies increasingly published journals in the 17th century, usually in their national language (Fjallbrant, 1997). The 18th century saw continued growth, although slow in the beginning and then rising toward the last quarter of the century with twenty-five new journals being published (Fjallbrant, 1997). Since journals also proved to be a much faster method to diffuse scientific findings than books or monographs and secured a reliable group of subscribers, they were increasingly recognized as the dominant form to disseminate scientific findings (Fjallbrant, 1997; Larivière et al., 2015).

The 19th century saw a strong increase in the number of journals with the mechanization of printing and a growing number of professional academics in newly established universities and colleges (Fjallbrant, 1997; Fyfe et al., 2015, 2017; Greco, 2020). The establishment of these new institutions meant new curricula with a growing body of professionals to both teach and research (Fyfe et al., 2017). Academics increasingly published their findings in reputable journals to secure professional positions, where their merit was evaluated based on their publications (Fyfe et al., 2017). In the 19th century, scientific publishing was characterized by the diversity in authoritative and trustworthy formats for publishing, which included monographs, pamphlets, collections, encyclopedias, and periodicals, while the 20th century quickly saw the market consolidate authoritative venue type toward scientific journals (Csiszar, 2010).

Derek de Solla Price's (1963) influential study on the number of new journals per year shows that journal publishing grew exponentially with the number of periodicals doubling every 10-15 until the 1960s (Price, 1963). Following Price's work, studies demonstrate a continued growth with the number of journals growing globally, from the 18th century to the world wars (Bornmann & Mutz, 2015), through the 80s (Fyfe et al., 2017), and even in the first decades of the 21st century (Larivière

et al., 2015). These periods of growth demonstrate the scientific community's increasing dependency on the journal as a tool to disseminate findings. While there were no profits in scientific publishing in the 18th and 19th centuries when learned societies and university presses managed the costs of knowledge dissemination, the 20th century saw the commercialization of journal publishing (Fyfe et al., 2015, 2017). After the Second World War, new markets emerged with increased funding of university libraries, the rapid growth in the university sector, both with rising student numbers and academics, new agencies and research centres, and national funding models (Fyfe et al., 2017; Greco, 2020; Guédon, 2019). Greco (2020) specifically points to 1945 as a "tipping point" for the US market to open to scholarly publishers with scientific discoveries generating new journals across the science, technical and medical disciplines (STEMM), and social sciences and humanities (SSH) (p. 22). Commercial publishers emerge to profit in this new market, moving control away from the community's learned societies (Fyfe et al., 2017; Greco, 2020; Guédon, 2019). Between the 1950s and 1970s, publishers employed new business tactics that enabled a commercial model of publishing where profits could be made (Fyfe et al., 2017). Fyfe et al. (2017) explain that these "mission-oriented publishers" employ a threefold strategy focused on setting up new journals with primary research focuses; selling journals to institutions; and expanding into a global market (p. 17). However, at this point, the goal was to break even and to offset the costs of dissemination in print, not generate large profits (Fyfe et al., 2017). Nevertheless, this emerging commercial market started to shape scholarly publishing in new ways.

After the Second World War, universities saw large periods of growth. At the same time, these institutions established more rigorous tenure and promotion processes, where "the publish or perish" model emerged (Greco, 2020, p. 2). Under the publish or perish model, journal publications increasingly became units to measure the credibility of both the science and scientist, placing

pressure on academics to increase their volume of publication outputs. Commercial publishers adapted editorial processes as they started to manage review processes, moving refereeing away from traditional learned societies and university presses (Baldwin, 2017b; Fyfe et al., 2017). External refereeing started to take place with the rise in grant funding and came to represent scientific respectability, providing accountability for the use of public funds (Baldwin, 2017b). In the 1960s, journals increasingly require external refereeing and recruit academics as editors and reviewers (Baldwin, 2015; Fyfe et al., 2017). Although a deeper analysis of peer review is outside the scope of this study, it is critical to point to its history and how commercial publishers legitimized their services through the free labour of academics. Publishers present peer review as their value-added to the publishing process, controlling for the quality of the research. The review process depends on high-quality review as this lends to the journal's credibility, attracting submissions (MacDonald & Eva, 2019). However, the publisher's value-added depends on the academic community to perform the work for free to the publisher, from the author who creates the content to the editors and referees who review the content (Buranyi, 2017; Haustein, 2012; Logan, 2017).

As the 20th century progressed, commercial publishers focused strategies on selling the trustworthiness of their journals and legitimatizing their roles in an ever-expanding market. Academics considered different characteristics of the journal, such as measures of prestige like citation index, who makes up editorial boards, star publications, and reach/impact (Greco, 2020). In addition to measures of prestige shaping commercial publishers, so did the control over author rights. In 1969, Franz Ingelfinger, the publisher of the *New England Journal of Medicine*, introduced a rule, known as the Ingelfinger law, that prohibits authors from submitting manuscripts to more than one journal as a way to protect the journal's revenue (Fanning et al., 2020; Haustein,

2012; Ingelfinger, 1969; Netland, 2013). Other journals began to similarly adopt this rule, with authors signing a declaration not to publish in other journals (Haustein, 2012).

These measures were more firmly established following the establishment of Eugene Garfield's *Science Citation Index (SCI)*. In 1961, Garfield, alongside Irving H. Shear, developed the SCI and its associated journal impact factor (JIF) and provided the database for the growth and large-scale applicability of bibliometrics / scientometrics (Garfield, 2006). Garfield, an information scientist, proposed an index to deal with the inefficiencies of retrieving information in a growing body of literature. Alongside the index, Garfield devised the JIF to rank journals by the average number of citations per article (Baldwin, 2017a; Haustein, 2012). The JIF was presented as a “cost-benefit calculation”, offering academic libraries a way to quantitatively evaluate relevant journals that meet their financial or disciplinary needs (Haustein, 2012, p. 348). However, the JIF was quickly abused as a metric that inaccurately measures the performance of both the journal and the author. Although a deeper historical analysis and examination of the JIF's limitations is outside of the scope of this study¹, it is worthwhile to point to its misuse and highlight how it continues to play a pivotal role in scholarly publishing that influences the market.

Twentieth-century developments, like the JIF becoming synonymous with legitimacy, coincided with the commercial publisher's foothold in the scholarly publishing system. Growth in scholarly publishing not only continued to rise throughout the 20th century but saw its strongest increase lasting until the beginning of the 21st century (Bornmann & Mutz, 2015). While the scholarly market grew during this period, academic libraries began to experience financial constraints, eventually leading to the first serials crisis for print (Shu et al., 2018). Research budgets essentially

¹ see Archambault & Larivière's 2009 study for a discussion on the consequences of the JIF

grew faster than library budgets (Johnson et al., 2018), and commercial publishers continued to charge immense fees for their journals while generating a return on investment as large as 25% (Lorimer, 1997). Academic library budgets essentially could not keep up with the inflated subscription market, and even more, could not compete with such tactics like price discrimination that commercial publishers engaged in when negotiating big deals (Edlin & Rubinfeld, 2004; Shu et al., 2018). Edlin and Rubinfeld (2004) explain the concentration in ownership within academic publishing enabled a market where the publishers with the biggest monopoly could apply tactics to enable Big Deals and bundling. In the 1990s, the publishing market experienced a consolidation as large commercial publishers started to both acquire existing journals and publishers, and create new journals (Larivière et al., 2015). At the same time, their profits continued to increase. This approach entrenched the oligopoly in the publishing industry, where they could control much of the market and dictate pricing. Christianson (1972) explains that the strategy of mergers and acquisitions was used as a business method to survive and is seen as a common activity in major industries. Taking control of the market enables a company to pool resources and activities; participate in growth areas; enter developing markets and ensure proper participation during early growth; and acquire companies already active in development (Christianson, 1972). These types of activities can ensure a company can sustain change, and endure economic challenges, like recessions. As this section explains, we see that the oligopoly of publishers take this very approach. Academic libraries, as a consumer, could not compete with the oligopoly's tactics, who exploited their power over the market.

2.2 The Digital Transformation and Birth of OA

In the more than 350 years since the origins of *Journal des Sçavans* and the *Philosophical Transactions*, the core features of the publishing process have remained relatively constant

(Guédon, 2019; Larivière et al., 2015). Despite new technologies and innovations like the internet, which provides the industry with a wider and faster reach to disseminate findings, scholarly publishing continues to rely on historical approaches that enable market dominance by an oligopoly. The OA movement emerged in the 1990s with the acceleration of digital technologies and the age of the Internet, where we see early sharing and practicing of findings and content with computer scientists, physicists self-archiving in pre-print servers like Arxiv (Fyfe et al., 2017; Haustein, 2012; Larivière et al., 2015; Pinfield et al., 2020).

The term OA was first formalized in three public statements a decade later. In 2002, the Budapest Open Access Initiative (BOAI) granted OA its most famous definition as literature that is publicly available online, free of charge, unrestricted, discoverable, free of most copyright and licensing restrictions, and is available for re-use (BOAI, 2002). The BOAI definition of OA includes licensing considerations, where users are free to copy, redistribute, and reuse content. However, other OA definitions exclude licensing requirements and focus more on free access (Piwowar et al., 2018).

It is important to understand the historical legacy of commercial publishing since we are seeing their infiltration into the OA market. OA was presented as a solution to the serials and accessibility crises (Suber, 2012). Yet, the oligopoly has established itself as the gatekeeper, firmly footed since the digital era.

2.3 OA Models

Dozens of models have emerged since the early days of OA. The more common OA models 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. The different OA models are not always mutually exclusive. For example, gold or hybrid OA articles can also be green if they are self-archived by the author. Moreover, some models consist of a variation or a more precise facet of a pre-existing model. For example, diamond OA are gold OA journals that do not charge APCs. Technically, the BOAI recommends two strategies – the diamond or green route – to achieve wider dissemination and access to scholarly literature, as the emphasis is on removing fees as a barrier (BOAI, 2002). In the context of this study, the green, gold, hybrid, and diamond models are compliant with the TAOAPP. However, this study focuses on gold and hybrid since they are the two models that charge APCs. These models will be discussed in more detail throughout this section.

2.3.1 Article Processing Charges

APCs, or the author-pays model, is where publishers charge authors a fee to make their article OA in fully OA (gold) or subscription (hybrid) journals (see section 2.3.2 and 2.3.3 for a discussion on APCs in gold and hybrid journals). This model essentially shifts the paywall from the reader (through subscriptions paid by libraries) to the author, their institutions, or funding agencies (Björk & Solomon, 2015; Simard, 2021; Solomon & Björk, 2012). Although early on, OA journals were voluntary efforts that did not charge fees, in 2002, a new group of publishers appeared who published using electronic means and relied on APCs to fund their operations (Björk & Solomon, 2015). Journals that charge APCs continued to grow, eventually expanding the publisher model to include players like Public Library of Science (PLOS) and BioMed Central, who publish OA mega-journals. As these new publishers continued to see growth in the OA market, traditional publishers, like the oligopoly, began establishing themselves by launching new OA titles,

providing a hybrid option for subscription journals, acquiring fully OA publishers, and converting subscriptions to full OA (Björk & Solomon, 2014).

APCs average anywhere from USD\$1,300² to \$3,000 depending on the type of journal (see sections 2.3.2 and 2.3.3 for a discussion of these averages). However, the oligopoly of publishers charges in the higher end of the spectrum of APCs (see Table 1), with Springer-Nature recently announcing an APC of \$11,200 per article (Noorden, 2020). Several studies have evaluated the criteria publishers apply when pricing APCs, finding a correlation between price and the prestige/reputation of the journal (Asai, 2020; Björk & Solomon, 2015; Khoo, 2019; Schönfelder, 2020; Siler & Frenken, 2020). The linking of price to prestige is a tactic the large commercial publishers, like the oligopoly, can employ owing to their sheer market power. The oligopoly was able to use their dominance in the traditional market to quickly establish themselves as leaders in the emerging OA market in the face of competition from new players such as PLOS, MDPI, Frontiers, and others. Their market power translates to APCs, where they can apply tactics like price discrimination, charging higher APCs and subscriptions for high-impact journals, which many authors and libraries are willing to pay due to the prestige and influence that these journals have on the academic reward system (Brembs, 2017; Khoo, 2019; Shu et al., 2018; Siler & Frenken, 2020). Mergers and acquisitions as well as general growth of publication output led to further consolidation of the market, allowing these publishers to control APC prices.

² All prices in this study are represented in USD unless otherwise stated.

Table 1. APC prices by individual scientific publishers for fiscal year 2018.

Publisher	APC fee
Wiley	\$2,000 to \$4,500
SpringerOpen	\$1,000 to \$1,400
Springer-Nature	\$1,100 to \$5,200
Elsevier	\$1,100 to \$4,500
Emerald	\$0 to \$3,000
American Chemical Society	\$1,250 to \$5,000
De Gruyter	\$500 to \$1,000
Cambridge University Press	\$600 to \$4,500
Hindawi	\$500 to \$2,500
PLOS	\$1,500 to \$3,000
SAGE	\$400 to \$3,000

Note. From (Simard, 2021, p. 51)

To pay APCs, authors must rely on grant funding, block grants, OA agreements, institutional financial support, or pay out of pocket (Dallmeier-Tiessen et al., 2011; Monaghan et al., 2020; Pinfield et al., 2016). However, not all authors can afford APCs as this is intricately linked to the privilege of resourcing, either in the form of grants, institutional prestige, career stage, language, discipline, gender, or geography, namely that the Global North can afford these fees (Olejniczak & Wilson, 2020; Siler & Frenken, 2020). The APC model, then, further exacerbates inequities within the academic system.

While APC waivers and other initiatives such as the Research4Life program do exist, they may be insufficient to overcome inequalities in academic publishing. Rouhi, Bears, and Brundy (2022) discuss how APCs worsen inequalities since the existence of waivers demonstrates the model works best for well-funded researchers and institutions — often those in the Global North — as well as disciplines. Waivers do not solve equity issues because they often exclude hybrid publishing or cover only a share of high APCs, leaving an unaffordable amount to the author in a Low-to-Middle-Income Country. The existence of such programs and initiatives illustrates the

problematic nature of the APC model and the inequities it creates. Initiatives to (temporarily) open access to literature and data during the Covid-19 pandemic, illustrates the inequities built into the overall system, where during times of crisis it becomes clear the economic barriers restrict scientific advancement.

2.3.2 Gold

Gold OA represents articles published in a scientific journal where all articles are published free of charge on the publisher's website immediately upon publication (Archambault et al., 2014; Gargouri et al., 2012; Piwowar et al., 2018; Suber, 2012). Most gold OA journals are free to read and free to publish. For example, nearly 70% - 12,647 out of 18,300 - of journals indexed in the DOAJ do not charge an APC (DOAJ, 2022). However, most OA articles are published in APC-based journals (Crawford, 2019). For gold OA journals that do rely on APCs, the average author fees range from \$1,371 to \$2,000 (Crawford, 2022; Jahn & Tullney, 2016; Morrison et al., 2021b; Solomon & Björk, 2016).

Archambault et al. (2014) estimate that the number of gold OA articles in Scopus increased by 18% per year from 1996 to 2012. This means that the proportion of peer-reviewed gold articles grew from 0.9% of all Scopus articles in 1996 to 12.8% in 2012 (1.3 million). Similarly, Piwowar et al. (2018) estimate that between 3.2% and 14.3% of scholarly articles published between 2009-2015 are available as Gold OA. More recently, Simard (2021) found that 10% of the literature indexed in WoS is available as gold, but highlights WoS limitation in capturing all gold content due to WoS' criteria to index each discipline's most important journals.

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 APC spent by German institutions uses data

from OpenAPC, an initiative that relies on self-reported APC cost data, while Solomon and Björk's (2016) study triangulated data from WoS, APC list prices collected by Morrison et. al in 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 consideration when calculating averages is the unit of analysis of the study. For instance, a study focusing on journals as a unit of APC (one APC per journal) analysis will strongly differ from a study based on individual papers (one APC per paper). The former estimates the APCs of journals offered, while the latter represents the APCs paid. Siler and Franken (2020) illustrated this phenomenon using data from the DOAJ. Recently, there has been a lot of discussions about the so-called diamond (previously called platinum) OA model which aims to make publication free for both authors and readers in order to promote non-profit publishing in OA and remove barriers to science for both readers and authors (cOAlition S, 2020; Bosman et al., 2021). Since diamond OA describes gold OA journals without APCs (APC=\$0), we consider diamond OA as a subcategory of gold OA for this study.

2.3.3 Hybrid

Originally suggested as a transitional phase to flip subscription journals to OA, (Björk, 2012; Prosser, 2003), the hybrid model describes subscription journals that allow authors to pay APCs to switch the status of an article to OA (Archambault et al., 2014; Björk, 2012; Eve, 2014; Laakso & Björk, 2016; Piwowar et al., 2018; Suber, 2012). Publishers developed the hybrid model as a way to provide an OA option to authors of articles published in paid journals and to compete with the pressures of gold OA journals (Budzinski et al., 2020). Large publishers now offer hybrid options for most of their journals and market it as their solution to OA (Springer-Nature, 2020; Wiley, 2019, p. 25). Hybrid OA has been criticized by the scientific community for its high APCs,

as well as the potential for publishers to double-dip—the practice of receiving two different sources of revenue for the same article—in the form of APCs and subscriptions (Eve, 2014; Matthias, 2018; Pinfield et al., 2016; Suber, 2012). Previous studies have shown the average APC for hybrid journals is around \$3,000 (Björk & Solomon, 2014; Shamash, 2016; Solomon & Björk, 2016). Springer-Nature set the trend for this \$3,000 average through their OpenChoice program in 2004, which was followed by most large commercial publishers (Björk & Solomon, 2015; Copiello, 2020).

While hybrid was presented as a way to transition the publishing market from subscriptions to OA, this model has not achieved this goal and instead continues to grow. Laakso and Björk (2016) track the uptake of hybrid articles amongst the oligopoly between 2007 and 2013 and found growth from 666 articles to 13,994 articles, a twenty-fold increase with a doubling in numbers almost every year. These numbers indicate that more researchers are using hybrid to publish articles as OA and that the broadscale switch of these journals to gold is still not in place. Laakso and Björk's (2016) comprehensive method of collecting articles from the open web and then performing the time-consuming task of cleaning the data demonstrate the challenge to study hybrid articles due to the lack of publisher standardized metadata (Laakso and Björk, 2016). Unpaywall, an open database that harvests OA content using an article's DOI, has since proved a more efficient method to track OA. In a recent study, Jahn, Matthias, and Laakso (2022) use Crossref metadata and text-mine APC invoicing data to examine Elsevier's uptake of hybrid OA. The authors find 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% (Jahn et al., 2022).

2.3.4 Bronze

Piwowar et al. (2018) introduced bronze OA to reflect the increasing occurrence of free-to-read articles on publishers' websites without licensing information. Like gold and hybrid, bronze articles are hosted by the publisher on a website but unlike gold, bronze articles are not published in a journal indexed in the DOAJ and do not carry a license like hybrid articles (Costello, 2019; Kirkman & Haddow, 2020; Paquet et al., 2022). Furthermore, it is unclear whether bronze articles represent full and permanent OA as they lack a creative commons licence that would allow reuse and includes articles that publishers may only make free to read for a limited amount of time (Costello, 2019; Paquet et al., 2022; Piwowar et al., 2018).

2.3.5 Green

Green OA can be defined as articles published in a subscription journal that are made openly available because authors have self-archived a version in an institutional or disciplinary repository (Gadd & Troll Covey, 2019; Harnad et al., 2008; Kirkman, 2018; Zhang & Watson, 2017). Although this study does not analyze green OA since there is no APC paid for these articles, it is an important feature of OA policies, and furthermore, a more equitable approach to OA than the APC model and therefore deserves a summary. Early advocates of OA perceived self-archiving articles as a way to circumvent the economic scholarly market, where authors do not pay to deposit an article in a repository (Nous, 2021). Even more, the original BOIA (2002) proposed self-archiving to achieve its goals of removing barriers and broadening access to research findings.

Many studies promote Green OA as an equitable publishing option as it is a cost-free option for authors, thereby removing an economic barrier and broadening the reach of access (Gargouri et al., 2012; Kirkman, 2018; Laakso & Björk, 2016; Zhu, 2017). Nevertheless, previous studies found

this option under-used compared to paying APCs to publish their article OA, and estimate that between 4.8% and 12% of all published articles are green OA (Bakker et al., 2017; Björk et al., 2014; Kirkman, 2018; Nous, 2021; Piwowar et al., 2018).

Many funders promote self-archiving as a route to compliance with their OA policy. However, there are often restrictions on which version can be deposited. For example, to comply with the TAOAPP, the accepted version must be the final peer-reviewed manuscript (Government of Canada, 2016). Navigating publisher policies when it comes to accepted versions has been an additional hurdle, with publishers often prohibiting the final version to be posted (uOttawa, n.d.). Sherpa/Romeo, a resource that aggregates journal OA policies, has provided libraries and authors with a tool to help navigate these policies and continue to promote the use of self-archiving in repositories (Sherpa/Romeo, n.d.).

2.3.6 *Transformative Agreements*

Similar to the original motivation of creating hybrid journals, transformative agreements (TAs) are meant to be transitory in a bid to move publishers toward full gold OA. In a read-and-publish agreement, an institution can access all publications and publish in journals without paying APCs for a bundled cost that is negotiated between the publisher and institution. The majority of TAs are with oligopoly publishers since the negotiations and the implementation of those deals require large investments (Hinchliffe, 2020). For example, 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 and gain access to 34 journals and 21 Nature Review titles (Noorden, 2020). This lump sum is based on a €9,500 (US\$11,200) APC fee per article (Noorden, 2020), which is almost four times the average hybrid APC of \$2,900 and more than eleven times the maximum of \$1,000 APC

recommended by the Fair Open Access Alliance (FOAA), an organization that evaluates sustainable OA publishing.

Transformative deals have been criticized for their lack of transparency (Esposito, J., 2018; Pooley, 2020; Poynder, R., 2018) and for continued exacerbation of the affordability problem within the scholarly publishing system. Many consider it highly problematic that instead of removing author fees, these deals merely carry APCs over into the agreement for a reduced cost (Borrego et al., 2020). Moreover, with Tas, publishers can also lock-in their prices, similar to Big Deals (Poynder, R., 2018). The shift from reader pays to author pays merely switches the commercial publishers' revenue sources from subscription to OA. Despite many efforts to lower subscription fees and the increasing adoption of OA, university libraries have increasingly been paying more to access scholarly literature (Simard, 2021). Instead of making scholarly publishing sustainable and accessible for all, high APCs and TAs seem to preserve the status quo and continue to exclude large parts of the academic community as well as the public.

Springer-Nature has announced other OA options they deem “low-cost options” in three specific journals (Brainard, 2020). These lower-cost options carry a €4,790 (US\$5,767) APC fee, as well as an initial fee of €2,190 (US\$2,635) to cover review costs, which do not guarantee publication. Such high OA fees, either through these new models or transformative deals, come at a price for authors and granting agencies and calls to question why certain commercial publishers reap such revenues from OA fees.

TAs will not be considered for the current study since the years examined ended in 2018, before their more widespread adoption³ (ESAC, n.d.).

2.4 Growth of OA

As more funders mandated OA, the volume of OA outputs increased (Piwowar et al., 2018). The increased rate of growth for OA led not only to more studies that explored the shape of this new market, but also the development of automated methods and tools, like Unpaywall, to access and explore OA outputs. Archambault et al. (2014) performed one of the earlier, comprehensive studies that used automated methods to track growth in OA. Using the Scopus database, Archambault et al. (2014) examined 500,000 articles and found that, at the time of data capture, 50% of scientific articles published between 2007 and 2012 could be downloaded for free on the internet, with a growth rate of 9.4% per year. Archambault et al. (2014) attribute the growth of OA at the time of their study to four forces: an increasing interest, at the time, in OA that led to more papers published as OA; older publications being converted to OA; OA policy embargo periods ending, which produces growth in old papers now available OA; and the overall growth in scientific publications (Archambault et al., 2014). Forces, such as older papers converted to OA and the expiration of the embargo period for a paper, contribute to what they call backfilling and OA's upward growth curve (Archambault et al., 2014). This finding is an important consideration for measuring growth in OA as it points to how operationalization and time of data capture can influence results, creating challenges to compare OA studies that employ different methods.

³ Refer to the ESAC Transformative Agreement Registry for relevant data on transformative agreements <https://esac-initiative.org/about/transformative-agreements/agreement-registry/>.

Using Unpaywall, Piwowar et al. (2018) found 28% of articles were available as OA but in their most recent year of analysis (2015), 45% of articles were OA. They found that growth was steady over the years and was primarily driven by gold and hybrid articles, whereas only 7% of the literature was green, although some green articles are also available as hybrid, gold, or bronze. More recently, we see the advancement of data visualization dashboards that track growth, such as the European Commission's (EC) Open Science Monitor (OSM) and the Curtin Open Knowledge Initiative (COKI) OA dashboard. The EC's OSM monitored OA outputs between 2009 – 2018 with the aim of providing data that supports policy development (Open Science Monitor, 2019). Like Piwowar et al. (2018), the OSM found that the rate of OA for gold, hybrid, bronze, and green continued to grow between 2009 and 2018, almost doubling in volume of publications (Open Science Monitor, 2019). However, they note a slowing of outputs in 2016 and a decline in 2017 and 2018 most likely owing to embargos on green OA (Open Science Monitor, 2019). Similar to Piwowar et al. (2018), the OSM report attributes the rate of growth in 2018 to the increasing volume of gold publications. These results highlight the revenue source for publishers through the author-pays model, which can rely on strong rates of growth, especially as global funders continue to mandate OA (see section 2.3.1 – 2.3.3 for a discussion on the growth of APCs in gold and hybrid OA). Aspesi et al. (2020) explain that publishers once justified that increases in subscription prices were due to the growing volume of published articles and that this approach, where publishers raise revenues alongside a growing market, will continue to support and raise publisher profits over time. We now see a similar approach with the APC model.

There are more than 125 countries publishing OA, with nearly half of the OA journals introduced between 2017 and 2020 (Pandita & Singh, 2022). The OSM tracked this growth in countries and found that the top five countries that saw the largest volume of OA publications were from the

Global North: the UK, Switzerland, Croatia, Luxembourg, and the Netherlands (Open Science Monitor, 2019). These results clearly demonstrate that the Global North is driving the growth of the APC model, where authors have access to more resources, either through grants or their institution (Olejniczak & Wilson, 2020), despite the diverse landscape of publishing that exists globally (Khanna et al., 2022).

The OSM ranked Canada amongst the countries with the lowest share of OA publications at 37.1% (Open Science Monitor, 2019). More recently, the COKI dashboard similarly finds this rate, at 38% (COKI, n.d.). These varying rates point not only to different publishing trends by each country, but also to the strength of the OA policy in promoting compliance and, accordingly, increasing rates of OA (see section 2.6 for more on rates of compliance in Canada).

2.5 The Publishing Market

The oligopoly's shift towards OA has happened in the context of an increasing number of Big Deal cancellations as well as a rise in funder OA mandates. For example, the Registry of OA Repositories (ROARMAP) shows that currently there are 1,113 OA mandates and/or policies, which has steadily risen since 2005 and started to level out around 2018 (ROARMAP, 2022). As more funders require OA, the volume of OA publications has also increased (Huang et al., 2020; Piwowar et al., 2018). Yet, this growth has not correlated with a decrease in APC fees, despite the increase in competition (Budzinski et al., 2020). Rather, there continues to be a consolidation of the publishing market, dominated by certain players like the oligopoly who drive pricing. Studies demonstrate the amount of money and profit to be made in the publishing system. In 2020, the global scholarly publishing market was valued at \$26.5 billion, with \$9.5 billion (36%) spent on journals (STM, 2021). Although the global challenge of COVID-19 slowed revenues for the

scholarly publishing market in 2020, some forecast it will rebound and continue to grow in the coming years (STM, 2021).

This large growth and market value drive the profit-driven model of traditional commercial publishing (Logan, 2017), which reaps obscenely high-profit margins (Smith, 2018). For instance, in 2017, Elsevier's 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). The high-profit model is founded on the work of academics who generally produce the labor as authors and reviewers as part of their jobs, free of cost to publishers (Buranyi, 2017; Logan, 2017). This mostly voluntary labor has been previously estimated to be about 1.9 billion in unpaid labor per year (Logan, 2017). While OA could theoretically overcome inequities in academic publishing, for-profit publishers have used APCs, and more recently Read-and-Publish deals (Pooley, 2020), to maintain a profitable business model. Regardless of the model — subscription or APCs — publishers generate these profits using university and funder budgets, which are often financed by taxpayer dollars.

Larivière et al. (2015) find that Elsevier, Wiley-Blackwell, Springer (before the merger with Nature in 2015), and Taylor & Francis dominate the scholarly publishing market, and publish more than half of the literature. Based on the number of active, refereed, academic journals indexed in *Ulrichsweb* (N=86,110 as of October 27, 2020) the biggest 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). The oligopoly's profit margins stem largely from subscription revenues, where they draw 68% to 75% of their revenues from university libraries (Ware and 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 4 years (Haigh, 2016). While prices for journal subscriptions have been rapidly increasing over the last few decades, library budgets have remained stagnant or decreased (Shu et al., 2018). As a consequence of these unsustainable costs, libraries have struggled to maintain their collections and ensure continued access to scholarly journals, in many cases cancelling their subscriptions.⁴ Yet, these cancellations have not stifled the market dominance of commercial publishers. Between 2014 and 2017, commercial publishers increasingly appear in the DOAJ (Crawford, 2022; Morrison, 2018). Rodrigues et al. (2020) looked at journals with the DOAJ Seal — a subset of DOAJ-indexed journals that adheres to best practices in OA publishing — and found that almost 65% of the total number of journals are published by a concentrated group of four publishers (BMC, Hindawi, Multidisciplinary Digital Publishing Institute & Springer Open). Since BMC and Springer Open are both part of Springer-Nature, Rodrigues et al.'s results underline the publisher's dominant position in the academic publishing market. The authors argue the concentration of these four publishers is bigger than the one described by Larivière et al. (2015) in a traditional scenario (Rodrigues et al., 2020).

With strong growth rates, commercial publishers have been shifting from traditional subscription revenue to APC-based OA models, re-establishing their dominance in the scholarly publication market. For instance, Simard et al. (2021) estimated that APCs paid to the oligopoly 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 during the same period. With strong growth rates, commercial publishers can shift from traditional subscription revenue to APC-based OA models.

⁴ See SPARC's Big Deal Cancellation Tracker: <https://sparcopen.org/our-work/big-deal-cancellation-tracking/>

Studies also show that publishers with higher revenues tend to charge higher APCs (Solomon & Björk, 2012; Pinfield, 2016). Khoo (2019) looked at four large OA publishers (BMC, Frontiers, MDPI, and Hindawi) to examine whether authors showed price sensitivity when selecting their APC-funded OA journal and found that APC fees rise once a journal sees an increase in article volume, demonstrating that authors continue to pay the fee despite the cost (Khoo, 2019). Furthermore, Khoo's (2019) study demonstrates that these publishers set higher APCs despite their increase in article volume, suggesting that potential economies of scale do not translate into reduced prices but are more likely into increased profits.

Zhang et al. (2022) use the latest available APC numbers from the DOAJ and publisher's and journal's websites and estimate that OA revenues from APCs in gold or hybrid journals by twelve major publishers alone exceed \$2 billion annually. This number exceeds Delta Think's projected \$1.1 billion, demonstrating the variance between studies based on data sources. Nevertheless, estimates from both studies illustrate the continued growth in the OA market, accounting for a reliable revenue source.

2.6 Funder OA Policies

The early OA manifestos advanced the argument for the right to free, unrestricted, and barrier-free access to publicly funded research and birthed the early beginnings of funder mandates. A funder's OA policy aims to increase access to publicly funded research and encourage a culture of openness to accelerate the discovery of funded research. How funders achieve the goals of an OA policy depends on their requirements and the support they provide. For example, some funders mandate their grantees deposit a version of their manuscript in a repository and provide such infrastructure support. In the United States, the NIH requires grantees to deposit peer-reviewed articles in

PubMed Central (NIH, 2016), while the National Science Foundation (NSF) requires principal investigators to deposit their peer-reviewed article or conference paper in their repository, hosted by the Department of Energy (DOE) (NSF, n.d.). Extending the US support for green OA even further, the White House Office of Science and Technology (OSTP) issued a memorandum (“OSTP memo”) on August 25, 2022, that directs all US federal granting agencies to require immediate OA to the research it funds, and that these publications be freely accessible in agency-designated repositories (OSTP, 2022). Mandating the deposit of articles in a repository, while providing the infrastructure, can circumvent the payment of APCs.

However, not all funders provide this infrastructure and some instead support the fees to publish OA to ensure grantees comply with their OA policy. As noted in section 1.2 of this study, the Canadian Tri-Agencies allow grantees to use their grant funds to pay for APCs. The UK Research and Innovation (UKRI) supports OA fees through block grants to eligible UK institutions, shifting the administration to institutions (UKRI, n.d.). Previous studies have critiqued the use of grant funds to cover APCs, especially for hybrid journals (Pinfield et al., 2017), and have cautioned about the essential need to closely track APC expenditures as the market grows and APC fees continue to rise (Shamash, 2016). An evaluation of OA policy requirements, and how these policies are situated into the overall ecosystem, is necessary when compliance depends on the use of grant funds that do not advance the research itself, but further support a business model.

Previous studies have found a low level of compliance with the TAOAPP (Larivière & Sugimoto, 2018; Paquet et al., 2022; Scaffidi et al., 2021). Larivière and Sugimoto (2018) performed one of the first studies to evaluate compliance with funder policies. The authors found varying rates of OA for the agencies between each agency, with CIHR having the highest levels of compliance and

SSHRC having the lowest. CIHR was an early adopter of the OA policy but found a decline in their rates – from 60% in 2014 to 40% in 2017 – once the agencies harmonized their policy (Larivière & Sugimoto, 2018). Scaffidi et al. (2021) similarly note a decrease in compliance for CIHR but at a different rate (from 79.6% in 2014 to 70.3% in 2017) most likely owing to the authors’ different methodologies of combining manual and automated methods. More recently, Paquet et al. (2022) analyzed the overall picture of OA rates in Canada and found an average of 44% of the articles are available as OA.

These studies note the challenges to complying with the TAOAPP, including a lack of supportive infrastructure like a national repository, a lack of enforcement with little consequences for non-compliance, and the influence of disciplinary norms and practices, including levels of funding, where STEMM fields receive more resourcing than SSH (Larivière & Sugimoto, 2018; Paquet et al., 2022; Scaffidi et al., 2021). These studies highlight the existing barriers for researchers to publish and how the TAOAPP could be amended to achieve more widespread access and dissemination of agency-funded research.

Publishers appear to be leveraging the growth in the OA market to shift business strategies from traditional subscriptions to OA, following global developments like cOAlition S’ OA publishing initiative Plan S, the OSTP memo, UNESCO’s *Recommendation on Open Science*, and increasing funder mandates and policies (cOAlition S, 2022; OSTP, 2022; UNESCO, 2021b). As of 2021, Plan S, a consortium of mostly European funders, is in effect and bans hybrid publishing (unless part of a TAs, see section 2.3.6), limits APCs paid for gold journals, and encourages subscription and hybrid journals to transition to become fully OA (cOAlition S, 2021). Plan S and the general

increase in OA mandates from funders worldwide has and will certainly impact the oligopoly's portfolios and business strategies (see section 2.3.6 on Transformative Agreements).

In Canada, the Fonds de recherche du Québec (FRQ) signed Plan S (FRQ, 2021) and the Office of the Chief Science Advisor published a *Roadmap for Open Science*, mandating federal science departments to publish their research in the open (Government of Canada, 2020). Although the Roadmap does not apply to research funded by the Tri-Agencies, it nevertheless will influence the Canadian system as many academics collaborate with federal scientists (Owens, 2022). Beyond the national context, Canada has a strong international network. Between 2017-2019, 56% of the share of Canadian publications are co-authored with international partners (UNESCO, 2021a). These collaborative networks are an important consideration for OA policy development as Canada will need to ensure its researchers can adapt to the international context to remain competitive.

3. METHODOLOGY

3.1 Study Design and Aim

This study aims to estimate the amount of OA fees paid for articles that acknowledge funding by the Canadian Tri-Agency (CIHR, NSERC, SSHRC) to oligopoly publishers Elsevier, Sage, Springer-Nature, Taylor & Francis and Wiley between 2015-2018. The study employs bibliometric methods combining data from the WoS, Unpaywall, open datasets of APC list prices (Butler et al., 2022a; Matthias, 2020b; Morrison et al., 2021a) as well as historical APC fees manually retrieved via the Internet Archive Wayback Machine (Wayback Machine). The methodological approach is to estimate the total amount of APCs (for gold and hybrid journals) paid by each publication that acknowledges a Tri-Agency funder/grant for 2015 - 2018.

3.2 Overview of Data Sources

Broadly, there are three sources of data used in this study: WoS, Unpaywall, and APC datasets (see Table 2). These data sources are linked to the study's four variables: APC prices, OA status of the article, acknowledgment of a Tri-Agency Funder (CIHR, NSERC, SSHRC), and publisher (see Table 3). Details on the method of collecting the data is explained in section 3.3.

Table 2. Data sources

	Source	Rationale
1	Web of Science (WoS)	Identify journal articles that acknowledge Tri-Agency (CIHR, NSERC, SSHRC) funding between 2015 and 2018 (inclusive); identify Canadian affiliation, DOI, publication year, discipline and other article metadata.
2	Unpaywall	Collect data on the OA status (gold or hybrid) of each article and year combination using the DOI.
3	Open APC datasets (Butler et al., 2022a; Matthias, 2020b; Morrison et al., 2021a)	Provide journal and publisher APC list prices

Table 3. Variables and data sources

	Variable	Data source
1	Article processing charge (APC)	Open APC dataset (Matthias, 2020; Morrison, 2021) + manual retrieval of APC prices from the Wayback Machine
2	OA status of article (hybrid or gold)	Unpaywall
3	Tri-Agency Funder (CIHR, NSERC, SSHRC)	WoS (funder acknowledgements)
4	Publisher	Open APC dataset (Butler et al., 2022a; Matthias, 2020; Morrison et al., 2021a)

3.3 Data Collection

3.3.1 Publications

Peer-reviewed publications published between 2015 and 2018 were identified using a local copy of the WoS database and queried using SQL. Document types were restricted to articles and reviews as these include original research findings and include APC fees. Other document types, such as conference proceedings were excluded from analysis as they are sometimes exempt from

APCs or paywalls. Publications were further restricted to include only those with a DOI to retrieve their OA status via Unpaywall (see Table 2).

To identify all journal articles controlled by the oligopoly of academic publishers, imprints and/or subsidiary publishing companies were manually assigned to the parent oligopoly company, using information available on the journal website and publisher press releases. 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. This method was similarly performed in Larivière, Haustein, and Mongeon's (2015) study, where the authors identified and associated subsidiary companies acquired by the oligopoly, using the Lexis Nexis database and the publisher's press releases. Larivière et al. (2015) explain that changes, like publisher names, due to acquisitions or mergers are not always immediately reflected, and/or publishers distribute their acquisitions in a portfolio of companies. A total of 136 imprint publishers (see Appendix B) were assigned to one of the five oligopoly publishers.

3.3.2 *Open Access Status*

The April 2020 snapshot of the Unpaywall database was used to obtain the OA status (gold, hybrid, bronze, green, closed) of each publication in the dataset. Unpaywall harvests legal content from Datacite, the DOAJ, Crossref, and PubMed Central, as well as from over 50,000 journals and repositories (Unpaywall, n.d.). Unpaywall assigns each DOI to one of the following categories:

- Gold (i.e., published in a gold OA journal)
- Hybrid (i.e., OA publication published in a subscription journal)
- Bronze (i.e., OA publication without license)
- Green

- Closed (i.e., No open access version of the article found by Unpaywall)

Only articles published in gold or hybrid journals were of interest since APCs are tied to these journal types. Articles published via a green OA route, such as those deposited in an institutional repository, were excluded since APCs are exempt.

Articles categorized as bronze were excluded as it is unclear whether these articles represent full and permanent OA as they lack a creative commons license that would allow for reuse. Bronze articles are not published in a journal but are instead hosted on the publisher's website. However, it may be possible that APCs were paid for articles categorized as bronze. There is some evidence that the bronze category includes articles that publishers make free to read for a limited amount of time (Costello, 2019; Piwowar et al., 2018). We, therefore, suspect that no APCs were paid for bronze articles, and therefore excluded them from our study. However, it should be noted that it might be possible that APCs were paid for articles flagged as bronze by Unpaywall. In this case, this study would significantly underestimate the total amount of APCs paid, particularly for hybrid articles. Of the 259, 370 articles with a DOI that included a Canadian affiliation, 9% were categorized as bronze, and of the 129, 140 articles with a Canadian affiliation that are published by the oligopoly, 5.0% were bronze.

3.3.3 *Journals and 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 prices for articles published between 2015 and 2018, whenever possible. Although current APCs are much easier to retrieve from journal websites and/or price

lists released by publishers, we argue that using current APCs for older publications could potentially overestimate actual fees paid. For example, in 2015 Wiley charged an APC of \$3,000 for publishing a hybrid article in the journal *Developmental Science*, while the current (September 2022) price is \$3,900. This approach was taken in a recent publication by Zhang et al. (2022) who note the difficulty of obtaining APCs.

We identified historical annual APCs in USD using a combination of data sources. First, APCs for gold and hybrid journals were derived from an open dataset created in April 2020 (Matthias, 2020b), which includes annual list prices in \$US for Elsevier, SAGE, Springer Nature, Taylor & Francis, and Wiley to provide an overview of their OA journal portfolios over time. The dataset consists of several data sources - subscription and APC price lists, gold, and hybrid OA title lists, and website snapshots - that were manually collected through the Wayback Machine and were at one point available through the publisher's website. The dataset lists the following information for every year (2010-2018): 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 17,736 of 19,317 journal-year combinations from Matthias (2020b).

To retrieve missing APCs for gold journals, we used another open dataset by Morrison (2021a), which provides annual APCs and metadata (e.g., journal title, print, and e-ISSN, publisher) for journals listed in the Directory of Open Access Journals (DOAJ). APCs are based on a previous dataset from Crawford (2019), DOAJ, and frequent manual checks on journal websites over a period of 10 years (2011-2021). 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 (2021a).

For journals missing APCs regardless of year, we manually searched for historical list prices using the Wayback Machine to access historical snapshots of journal websites maintained by the publisher and/or academic societies that were affiliated with the journal. The Wayback Machine's Google Chrome plugin browser⁵ was installed to speed up the search process. The plug-in allows users to select the earliest, oldest, or calendar view of archived pages, where users can select the preferred year of archived data. The Wayback Machine's calendar option highlights each day a particular page was archived in blue, green, and sometimes red. Blue directly links to the preferred page and was therefore selected first when searching for a particular journal page. Green, on the other hand, is a redirect and often leads users to a more recent version of the preferred page. Dates highlighted in green were only selected in the absence of a blue option. These redirects, however, could sometimes lead to another entry point for the desired page. Red circles on the calendar indicate server errors⁶ and were avoided.

This time-consuming process was performed for over 700 journal-year combinations, of which 320 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 an oligopoly publisher (n=203) or was a book or conference proceedings rather than a journal (n=11). APCs for 482

⁵ Internet Wayback Machine's plug in: <https://chrome.google.com/webstore/detail/wayback-machine/fpnmgdkabkmnadcjpehmllkndpkmiak>

⁶ Example of a server error: https://web.archive.org/web/*/https://journals.sagepub.com/home/gos

journal-year combinations were successfully obtained via the Wayback Machine and used in this dataset.

To verify the journal's acquisition date, we referenced the publisher's archived press releases in the Wayback Machine and/or other online sources, such as Wikipedia. This step of manually verifying acquisition dates was performed for all five publishers – Elsevier, Springer-Nature, SAGE, Wiley, and Taylor & Francis. Journals were removed from the dataset if the journal year (e.g. 2016) was earlier than the oligopoly publisher's acquisition date (e.g. 2017). For example, this process removed 60 Wiley journals from the dataset since Wiley acquired those journals after the year marked in the dataset. Wiley often announces journal acquisitions using the language of a “new partnership”, followed by the society name. Internet searches were therefore performed by entering “Wiley + journal/society name + partners with”. Often, the acquisition announcement could be captured within the first 1-3 results. Journals listed a year earlier than the acquisition date were removed from the dataset. For example, Wiley announced the publishing partnership with the *Society for Leukocyte Biology* on July 6, 2017, and indicated that they would begin publishing the *Journal of Leukocyte Biology (JLB)* in 2018⁷. However, the dataset included 2015, 2016, and 2017 for that journal, which was subsequently removed.

Like Wiley, SAGE announces acquisitions in their News Room⁸, and also published a list of their journal acquisitions in 2016⁹. This process removed 54 SAGE journals from the dataset (see Table

⁷ See Wiley's news announcement on their partnership with Leukocyte Biology <https://www.stm-publishing.com/the-society-for-leukocyte-biology-and-wiley-announce-publishing-partnership/>

⁸ SAGE Publishing's News Room: https://us.sagepub.com/en-us/nam/press-releases/2018?_gl=1%2Ab8qwyz%2A_ga%2AMTM1ODUxODg4Mi4xNjMxNTg2MTY0%2A_ga_60R758KFDG%2AMTYzNjE1ODM5NC42LjEuMTYzNjE1ODg4OS4w%2A_ga_RK7MQ5ZZVZ%2AMTYzNjE1ODM5NC4yLjEuMTYzNjE1ODg4OS4w

⁹ List of journals acquired by SAGE in 2016: <https://web.archive.org/web/20160128213742/https://us.sagepub.com/en-us/nam/new-journals-and-changes>

3). Acquisitions by publishers Elsevier, Springer-Nature, and Taylor & Francis were not found in media announcements but were often announced on the publisher's website and archived in the Wayback Machine. For example, Elsevier announced a partnership with The Poultry Science Association and began publishing *Poultry Science* and the *Journal of Applied Poultry Research* as gold OA journals in 2020¹⁰, which meant removing 2015, 2016, 2017, and 2018 data; and Springer-Nature acquired *Chemical Central Journal* in 2018¹¹, which meant removing the 2015 and 2016 data.

Wikipedia was also used to verify the journal acquisition dates. For example, the dataset included four years of data for *Africa Spectrum* (2015, 2016, 2017, 2018), which was associated with SAGE. The journal's Wikipedia page, however, indicates it was published by the German Institute of Global and Area Studies (GIGA). A general internet search using the keywords "SAGE and *Africa Spectrum*" was performed to verify the publisher. This search led to the GIGA page¹² which indicates it was published by SAGE as of 2019. All four years of data (2015, 2016, 2017, 2018) were consequently removed from the dataset.

Some journals in the dataset were tagged OA but were in fact closed, had no OA information listed¹³, were not published by the oligopoly, had a change in OA status (e.g., was hybrid as of a

¹⁰ *Poultry Science* and Elsevier's Publishing Agreement announcement: https://web.archive.org/web/20210126114652/https://poultryscience.org/files/galleries/07-2019_PSA_Announces_a_New_Publishing_Agreement_Official_Press_Release-0001.pdf

¹¹ *Chemistry Central Journal* and BMC's (Springer-Nature) merger: <https://web.archive.org/web/20180919042831/https://ccj.biomedcentral.com/>

¹² <https://journals.sub.uni-hamburg.de/giga/afsp/>

¹³ See the SAGE journal *Index on Censorship* <https://us.sagepub.com/en-us/nam/journal/index-censorship#description>

date later than the year marked), or were a document type other than a research article (e.g., book)¹⁴. These entries were also removed.

Manually searching for APC list prices on the Wayback Machine presented several challenges, such as archived pages sometimes failing to load or redirecting users to the wrong page. SAGE web pages,¹⁵ out of the archived oligopoly webpages, most frequently fail to load and often prompt users to enter location details, such as their country, before users can navigate the webpage. In these instances, users can refresh and briefly scroll the page or close the location field to quickly capture the desired information.

It is possible to locate other access points to archived journal pages in instances when pages fail to load, if certain web pages are not archived each year, or if archived pages redirect users to the wrong page. For example, a journal's academic society website proved to be the most reliable access point to locate a publisher's APC information since Wayback Machine frequently archives society webpages. For example, Wiley publishes the journal *Genes to Cells* on behalf of the Molecular Biology Society of Japan. When no archived web pages for the journal were found before 2018 on Wayback Machine, a general internet search for the society website led to archived webpages dating back to 2011¹⁶. The 2015 archived data was selected, and from here a link redirecting the user to a 2015 Wiley page with APC information was located¹⁷. Even more helpful

¹⁴ A total of 12 book entries were removed, i.e. <https://www.sciencedirect.com/bookseries/international-review-of-neurobiology> or <https://link.springer.com/book/10.1007/978-3-319-74092-8>

¹⁵ SAGE webpage that failed to load:

<https://web.archive.org/web/20170920180043/http://journals.sagepub.com/action/cookieAbsent>

¹⁶ See The Molecular Biology Society of Japan's archived webpages here:

https://web.archive.org/web/*/https://www.mbsj.jp/en/index.html

¹⁷ See Wiley journal *Genes to Cells* 11 March 2015 archived webpage:

[https://web.archive.org/web/20150311100755/http://onlinelibrary.wiley.com/journal/10.1111/\(ISSN\)1365-2443/homepage/FundedAccess.html](https://web.archive.org/web/20150311100755/http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1365-2443/homepage/FundedAccess.html)

was that from this access point, a 2015 list of Wiley publications was found¹⁸, and missing APC journal prices for other Wiley journals were filled where possible.

Another challenge to locate APC information includes the oligopoly's lack of archived journal web pages in Wayback Machine between 2015 and 2019. However, by searching through society pages, or serendipitously selecting links within a page that direct users to other web pages, APC information could at times be located, such as the discovery of Wiley's APC price lists for 2016¹⁹, 2017²⁰, and 2018²¹. There is a significant lack of archived pages for Elsevier for the years 2015 to 2018, most especially for 2015. For information on OA fees, Elsevier will often direct users to the "guide for authors" for information on APC prices. However, in the guide, Elsevier directs users back to the journal homepage. This lack of transparency creates another challenge, especially when trying to locate archived pages as not all links within an archived page will be preserved. Elsevier also includes confusing language on whether certain journals charge APCs. For example, for their journal *Green Energy and Environment*, Elsevier includes the following note:

To provide open access, this journal has an open access fee (also known as an article publishing charge APC) which needs to be paid by the authors or on their behalf e.g. by their research funder or institution. The journal is currently free to the authors and readers.

¹⁸ Wiley's archived list of 2015 Journals:

<https://web.archive.org/web/20150318064018/http://onlinelibrary.wiley.com/browse/publications?type=journal&activeLetter=G>

¹⁹ Wiley's archived 2016 APC list prices:

<https://web.archive.org/web/20161003190333/http://olabout.wiley.com/WileyCDA/Section/id-829155.html>

²⁰ Wiley's archived 2017 APC list prices:

<https://web.archive.org/web/20170713012027/https://authorservices.wiley.com/author-resources/Journal-Authors/licensing-open-access/open-access/article-publication-charges.html>

²¹ Wiley's archived 2018 APC list prices:

<https://web.archive.org/web/20180702205150/https://authorservices.wiley.com/author-resources/Journal-Authors/licensing-open-access/open-access/article-publication-charges.html>

It is not clear, in this instance, if the journal charges a fee. It is possible that the journal is financed through an author-pays model or is diamond OA and the society pays the fee. In these instances, fees were set at \$0.

The dataset for the global data (Butler et al., 2022a) 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 (2020a) or Morrison (2021a) datasets, highlighting the challenges of gathering accurate historical APC prices from the web. 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 use the lower amounts in case of conflicts. This way, we are more likely to under- rather than overestimate the actual fees paid. An exception was actual APCs obtained through the 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) overall, with differences per publisher (Table 4). We should note that this difference applies to gold APCs only 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 4. Difference between lower and upper estimate of total APCs (in USD) per publisher

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	\$1,083,817	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 oligopoly 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 by different methods used for the analysis is shown in Table 5 below. The cost of OA was 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 the calculation of our estimates, as we do not have access to this information. The lack of discount and waiver information might lead to an overestimation of 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.

Table 5. 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	6,2212	86.1%
Matthias: newer	369	2.0%

Matthias: older	3690	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	9,468	4.9%
Matthias: actual Morrison: actual	03	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%

3.3.4 *Tri-Agency-acknowledged OA Publications*

Funding acknowledgements (FAs) were used as the data source to estimate the amount of APCs paid by Canadian researchers funded by the Tri-Council to publish OA (gold and hybrid) articles

between 2015 and 2018. The TAOAPP requires grant recipients to acknowledge the funder (CIHR, NSERC, or SSHRC) in their peer-reviewed publication, and quote the funding reference number (Government of Canada, 2016). Authors will usually cite the funder and grant number in the acknowledgment section at the end of the paper. Since 2008, WoS includes FAs for science and medicine, and since 2015 for social sciences articles, which allows for better tracking of funded research (Larivière & Sugimoto, 2018).

There is a large body of research on the topic of FAs, as noted in a meta-synthesis (Desrochers et al., 2017) and literature review (Álvarez-Bornstein & Montesi, 2021) of the topic, which explores the behaviour of acknowledgements and limitations of this data source. FAs have been studied for 50 years with Cawpord and Biderman (1970) first examining acknowledgements found in footnotes, then with Cronin's (1996) study exploring author behaviour on what Desrochers et al. (2017) note as "the parallels and differences between recognition and symbolic capital" of acknowledgements (p. 2822). Giles and Councill's (2004) study was the first to use natural language processing to extract acknowledgements. From the CiteSeer computer science archive, the authors mined 188,052 acknowledgements from 335,000 research publications and combined it with citations to measure impact (Giles & Councill, 2004). Their results examine the distribution of acknowledgements to four "entities": funding agencies, corporations, universities, and individuals. Giles and Councill's (2004) study demonstrates an early automated method of correlating acknowledgments with funding and provides one of the first automated methods to evaluate funding trends. Although there are limitations to FAs (described in section 3.6), FAs provide data that can yield useful findings on the patterns of authorship, collaborations, citations, and funding.

Funding data for this study was collected using the WoS and restricted to articles, years, and funders. There was a total of 198,403 (see Figure 1 in results section) UTs with a funding acknowledgement linked to an author with a Canadian affiliation. Since there is no standard format to acknowledge a funding agency, a step was taken to clean the variation of acknowledgments for each funder and tag it to a single entity – the funder’s acronym (CIHR, NSERC, or SSHRC). An additional search for each Tri-Agency’s grants was performed since it was found that many authors will cite their grant only and not the funding agency. The disambiguated and cleaned spelling variants of funder names and programs were linked with the APC dataset, as described in section 3.5.5.

First, a search for CIHR-related variations was performed. There was a total of 34,915 rows of acknowledgements with variations of CIHR funder name and grants including 4,905 unique variations which were all tagged in a new column as ‘CIHR’. For example, there were 2759 rows with the acronym of “CIHR” included in the author’s acknowledgment, which was subsequently tagged as CIHR. However, sometimes authors also acknowledged CIHR-specific institutes, like the Institute of Aging, which also required tagging to CIHR. This same method was applied to NSERC and SSHRC acknowledgements, where additional checks were performed to ensure authors that acknowledge any agency-specific grants were accordingly tagged.

During this process, it was noted that many of the grants in the dataset were jointly administered by the three agencies. These grants were assigned to a category titled “jointly administered” as it is unclear which agency budget the grant derives from, and since these grants are awarded to students and professors in various disciplines. For example, the Vanier Canada Graduate Scholarships website states that “the program is administered by the Vanier-Banting Secretariat

(the “Secretariat”) on behalf of Canada’s three federal granting agencies” and is housed within CIHR (Government of Canada, 2022). The Secretariat is responsible for the “day-to-day administration...and provides support to the selection committee...” but it is unclear if the budget comes solely from CIHR, as the administering agency. There are also instances when an author acknowledges both their Vanier scholarship and their agency, such as “SSHRC Vanier Fellowship”. In those instances, it was unclear if the budget came from SSHRC. Another example includes the Canada Research Chair (CRC) program (Government of Canada, 2012). This program is a Tri-Agency initiative but is administered by the Tri-Agency Institutional Programs Secretariat (TIPS), which is “housed in SSHRC” (Government of Canada, 2012). Again, it is unclear if the disbursement of funds comes solely from SSHRC’s budget. Similar to the Vanier Scholarship, some authors attribute their agency when acknowledging their CRC, such as “Canada Research Chair program of Natural Sciences and Engineering Research Council of Canada”.

After cleaning the variations of Tri-Agency acknowledgements, a total of 139,033 rows with variations of the Tri-Agency funder names or grants remained. The next step was to remove duplicate documents (UTs). The dataset contains duplicate UTs if publications acknowledge more than one source of funding. For example, Shiell et al.’s (2015) article associated with UT 000345616600013 appears four times in the dataset since it acknowledges CIHR, NSERC, NSERC, and the Tri-Councils (Vanier Scholarship). Removing duplicate occurrences ensures that APCs are only counted once per publication and per funder. A total of 35,146 duplicates were removed, which left 103,886 rows of data containing UT and Tri-Agency funders.

3.3.5 *Linking the Datasets*

To estimate the amount of APCs paid to the oligopoly for articles that acknowledge Tri-Agency funding between 2015 and 2018, the three datasets – WoS publication data for 2015-2018 and OA status (gold or hybrid) for each publication; APC amounts for each oligopoly journal (gold or hybrid); and publications that acknowledge the Tri-Agencies (CIHR, NSERC, SSHRC, Jointly administered) – were linked using Excel for analysis.

To link these datasets, a unique source ID was assigned to each publication (UT and publication year). This source ID was then linked to the APC and funder data, allowing for the analysis of the three RQs.

3.4 **Limitations**

Although the rigour of our method in collecting historical APC list prices attempts to curb an overestimation of the amount of APCs paid to the oligopoly, there are nevertheless limitations to this study. First, there is not a comprehensive representation of publications by each Tri-Agency funder owing to the limitations of WoS. Studies that compare WoS to other databases like Scopus and Dimensions find that overall, the breadth of fields and coverage of non-English journals is lower (Basson et al., 2022; Mongeon & Paul-Hus, 2016; J. Zhu & Liu, 2020). Additionally, WoS disproportionately favours STEM fields so the coverage of publications that acknowledge SSHRC will be lower than CIHR and NSERC. By nature of the traditional forms of dissemination in SSH, SSHRC-funded researchers may publish fewer articles than CIHR or NSERC, and instead publish in forms such as monographs or books, which were not included in our analysis.

Second, relying on funding acknowledgements to capture publications that identify Tri-Agency grants limits the comprehensiveness of our coverage. Previous studies analyzed FAs and find the lack of a standard format creates challenges in studying trends or the societal impacts of research funding (Aagaard et al., 2020; Álvarez-Bornstein & Montesi, 2021; Grassano et al., 2017; Rigby, 2011). Rigby (2011) specifically finds that the lack of standardization creates errors such as misspelling of the funder, names of grants, or the grant number. Another challenge is that many authors fail to self-report their funder and/or grant (Aagaard et al., 2020; Costas & Yegros-Yegros, 2013; Desrochers et al., 2017; Koier & Horlings, 2015; Liu et al., 2020). We recognize that we rely on authors to self-report funding and challenges like the lack of standardization mean we may miss some publications that acknowledge Tri-Agency funding or a grant. Therefore, our study clarifies that the estimation of APCs is not representative of all Tri-Agency funded research, but instead of those publications that acknowledge a Tri-Agency funder or grant.

Third, our study is limited to providing an *estimate* of APC spent rather than a *calculation* as we could not account for possible discounts or waivers. In Canada, CRKN is a consortium representing 81 institutions that negotiates with publishers and vendors, including discounts on OA fees. Therefore, authors affiliated with a CRKN member institution may receive an institutional discount, which we cannot track at the article level. Previous studies that track APC spending similarly note the challenge in capturing actual amounts paid, owing to vouchers, institutional discounts, or prepayments (Pinfield et al., 2016; Shamash, 2016). We, therefore, clarify that our estimation of APCs paid to the oligopoly is based on list prices since we cannot capture the actual amount paid by the author for each article in our dataset. Nevertheless, our method rigorously ensures we under- rather than over-estimates APCs by applying historical list prices per journal-year combination, instead of applying current APCs to previous years.

Our data included multiple funders per publication, but it is also unclear which author in multi-authored publications paid the APC. Often, a single article acknowledges several Tri-Agency funders. For example, authors would sometimes acknowledge funding from both CIHR and NSERC, or SSHRC and NSERC. To eliminate double-counting APCs in these instances, we analyzed overall Tri-Agency spend by associating only one funder to the journal-year combination, categorizing this as “any Tri-Agency”.

Finally, we rely on Unpaywall’s classification of each article’s OA status based on the April 2020 snapshot. Unpaywall continuously updates its algorithm to ensure the accuracy of its classification system, which means some OA statuses can be reclassified (Sanford, 2022). Sanford (2022) explains that since the OA classification system changed from a two-class (open and closed) to a five-class system (gold, hybrid, bronze, green, closed), classifications must change from open to their associated colour. The possibility for reclassification highlights the instability of OA categories. While closed and gold are more stable classes, hybrid, green, and bronze are not as stable. For example, Sanford (2022) finds that 79% of items classified as bronze have previously changed status, sometimes up to five times. Therefore, the use of Unpaywall is a snapshot of OA status for the time of the study. In the larger global APC study, we demonstrated Unpaywall’s instability, noting a significant decrease in the number of hybrid publications, particularly for Elsevier, following an update from April 2020 to a March 2022 Unpaywall snapshot (Butler et al., 2022b). We hypothesized that the decrease was owing to a reclassification of many Elsevier hybrid publications to bronze (Butler et al., 2022b). Sanford (2022) explains that author identification of OA categories is usually more reliable than publisher selections. For the purposes of our study, it may similarly be possible that articles are reclassified in a future update of Unpaywall’s algorithm.

4. RESULTS

4.1 Overview of Data

There was a total of 419,821 publications with a Canadian affiliation retrieved from WoS between 2015 and 2018. As shown in Figure 1, 82.4% (n=346,086) of these publications included a digital object identifier (DOI). Of the total amount of publications with a DOI, 74.9% (n= 259,370) were classified as document type ‘article’, which represents original research papers. From this subset of research articles with a DOI, 76.5% (n= 198,403) included a funding acknowledgement, 52.0% (n= 103,147) of which acknowledged Tri-Agency (CIHR, NSERC, SSHRC) funding. From the subset of Canadian articles with a DOI that acknowledge Tri-Agency funding, 49.5% (n=51,086) were published by an oligopoly publisher, which confirms previous findings by Larivière et al. (2015) that the oligopoly of academic publishers controls approximately half of all articles indexed in WoS. Of the 51,086 research articles with a DOI published by Canadian authors in a journal published by the oligopoly, 21.5% (n=10,989) were gold or hybrid OA, with almost two-thirds published in gold OA journals (62.7%; n=6,892) and over one third (37.3%; n=4,097) as hybrid OA in paywalled journals (Figure 1).

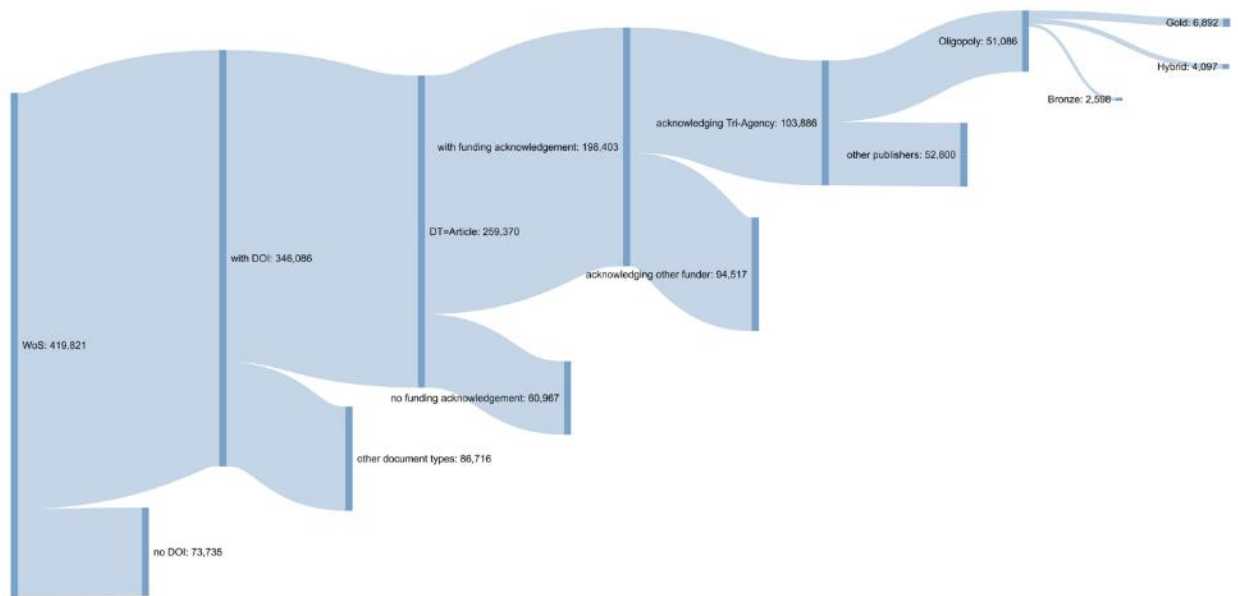


Figure 1. Sankey diagram of gold and hybrid Canadian articles acknowledging Tri-Agency funding in WoS 2015-2018

4.2 OA Rates for all Canadian and Tri-Agency Publications

We found that 46.0% (Table 6) of all research articles indexed in WoS with at least one author affiliated with a Canadian institution were published OA (including gold, hybrid, green, and bronze). At 48%, the rate of OA for publications that acknowledge Tri-Agency funding is only slightly higher than the Canadian rate with the oligopoly (38.6%) compared to all publishers (48%) (Table 6). These Tri-Agency findings indicate that over half of all papers do not adhere to the TAOAPP. Overall, CIHR published a higher percentage of OA articles than NSERC and SSHRC, with 64.7% (n=18,462) of OA articles published by any publisher and 55.7% (n=8,265) published by the oligopoly only (see Table 6).

When comparing how Canadian authors publish OA, self-archiving (i.e., green OA) receives the highest rates of OA for all publishers at 37.0%. Following green, Canadian authors publish more

content as gold (15.4%) than hybrid (7.4%), a trend similarly observed when articles are published by an oligopoly publisher only (12.1% gold; 8.8% hybrid). Our results indicate that Canadian authors publish higher rates of bronze (9.8%) than hybrid (7.4%) for all publishers. However, this trend is reversed for articles published only by an oligopoly publisher, where we see lower rates of bronze (5.0%) than hybrid (8.8%).

Similar to all Canadian-authored publications, authors who acknowledged Tri-Agency funding published a higher volume of green OA than any other OA category, with 39.5% of OA articles as green when published by any publisher, and 30.8% when published by an oligopoly publisher (see Table 6). Of the OA articles published by the oligopoly, Tri-Agency grantees published a higher volume of gold articles (13.5%, n=6,892) than hybrid (8.0%, n=4,097), but this trend differed by Tri-Agency funder. For example, CIHR published a higher volume of gold OA than NSERC and SSHRC, a trend that was constant for the subset of all articles (oligopoly and non-oligopoly) and for oligopoly-only articles (see Table 6). NSERC published more gold (10.7%, n=3,668) than hybrid (7.3%, n=2,424). However, SSHRC, unlike CIHR and NSERC, published a higher volume of hybrid (5.1%, n=211) than gold (3.0%, n=126).

Table 6. Percentage of publications (OA and non-OA) by authors who acknowledge the Tri-Agencies

%	Canada	Any Tri-Agency	CIHR	NSERC	SSHRC	Jointly administered
All papers	259,370	103,147	28,543	71,505	7,466	13,699
closed	54.0%	52.0%	35.3%	55.8%	69.5%	44.9%
any OA	46.0%	48.0%	64.7%	44.2%	30.5%	55.1%
gold	15.4%	16.5%	25.7%	14.3%	7.9%	20.6%
hybrid	7.4%	7.6%	10.0%	7.3%	3.9%	8.9%
green	37.0%	39.5%	53.3%	36.4%	25.3%	46.6%
bronze	9.8%	9.7%	17.7%	7.4%	4.1%	10.1%
All oligopoly	129,140	51,086	14,828	34,218	4,138	6,721
closed	62.0%	61.4%	44.3%	66.4%	74.1%	53.2%
any OA	38.0%	38.6%	55.7%	33.6%	25.9%	46.8%
gold	12.1%	13.5%	23.8%	10.7%	3.0%	19.4%
hybrid	8.8%	8.0%	11.7%	7.1%	5.1%	9.0%
green	30.1%	30.8%	45.3%	26.4%	21.1%	38.9%
bronze	5.0%	5.1%	8.7%	4.1%	2.1%	5.0%

4.3 Overview of Tri-Agency APCs

Combining the number of gold and hybrid publications with APC list prices, we estimate that for the publications that acknowledged Tri-Agency funding, authors paid the oligopoly of academic publishers \$25.3 million in OA publication fees, \$13.1 for gold and \$12.2 for hybrid (see Figure 2), for a total of 10,989 articles published in 4,341 journals between 2015 and 2018.

Authors who acknowledged CIHR paid \$13.7 million in APCs to the oligopoly, directing \$7.7 million to gold and \$5.9 million to hybrid (see Table 8). We estimate that for NSERC, a total of \$13.0 million was paid and that those totals were evenly distributed between gold and hybrid, with approximately \$6.2 million spent for gold and \$6.7 million for hybrid (see Table 8). For publications that acknowledged SSHRC funding, a total of \$719.9k was paid to the oligopoly. Like NSERC, SSHRC paid a higher amount for hybrid (\$535.0) than gold (\$185.0), which also mirrors

the overall Canadian trend, where authors affiliated with any Canadian institution paid more for hybrid (\$34.0 million) than gold (\$29.3 million) (see Table 7).

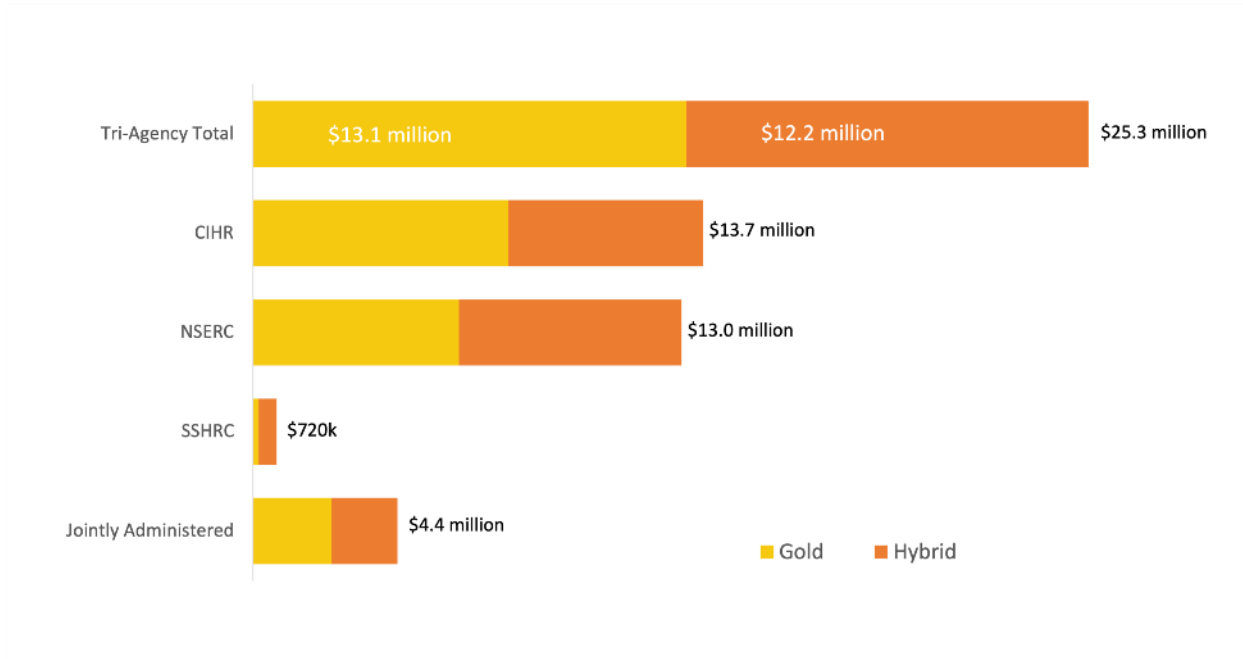


Figure 2. Total Hybrid and Gold APCs per Tri-Agency funder

Table 7. Total amount of hybrid and gold APCs for Canadian-affiliated and any Tri-Agency author per year (2015-2018)

	Canada		Any Tri-Agency	
	hybrid	gold	hybrid	gold
2015	\$ 6,666,232	\$ 6,616,475	\$ 2,673,290	\$ 3,143,926
2016	\$ 8,838,180	\$ 6,294,458	\$ 3,241,086	\$ 2,805,896
2017	\$ 8,946,233	\$ 7,533,797	\$ 3,065,542	\$ 3,273,873
2018	\$ 9,539,713	\$ 8,835,152	\$ 3,200,952	\$ 3,901,006
2015-2018	\$ 33,990,358	\$ 29,279,882	\$ 12,180,870	\$ 13,124,701

Table 8. Total amount of hybrid and gold APCs per Tri-Agency funder per year (2015-2018)

	CIHR		NSERC		SSHRC		Jointly administered	
	hybrid	gold	hybrid	gold	hybrid	gold	hybrid	gold
2015	\$ 1,339,890	\$ 1,954,725	\$ 1,491,845	\$ 1,393,994	\$ 74,850	\$ 43,390	\$ 348,300	\$ 514,886
2016	\$ 1,535,360	\$ 1,629,814	\$ 1,874,014	\$ 1,331,077	\$ 98,500	\$ 45,672	\$ 510,338	\$ 540,636
2017	\$ 1,414,078	\$ 1,864,637	\$ 1,694,222	\$ 1,605,145	\$ 170,150	\$ 47,128	\$ 507,947	\$ 592,582
2018	\$ 1,605,648	\$ 2,293,881	\$ 1,679,425	\$ 1,910,465	\$ 191,400	\$ 48,761	\$ 622,395	\$ 740,506
2015-2018	\$ 5,894,976	\$ 7,743,057	\$ 6,739,506	\$ 6,240,681	\$ 534,900	\$ 184,951	\$ 1,988,980	\$ 2,388,610

For publications that acknowledged any Tri-Agency funder, the amount of APCs and the number of OA articles increased annually over the four-year period from \$5.8 million for 2,381 articles to \$7.1 million for 2,906 articles (see Figures 3, 4, and 5). NSERC saw the largest increase in gold APCs paid to the oligopoly compared to the other funders, from \$1.4 million in 2015 to \$1.9 million in 2018, whereas CIHR’s amounts increased from \$2.0 million in 2015 to \$2.3 million in 2018. This higher APC amount is associated with the higher volume of publications reported for CIHR and NSERC (see Figures 4 and 5). On the other hand, authors who acknowledged SSHRC funding increasingly paid more in hybrid fees than gold (see Table 7), from \$74.9k in 2015 to \$191.4k in 2018, whereas SSHRC’s gold OA fees remained relatively stable from \$43.4k in 2015 to \$48.8k in 2018.

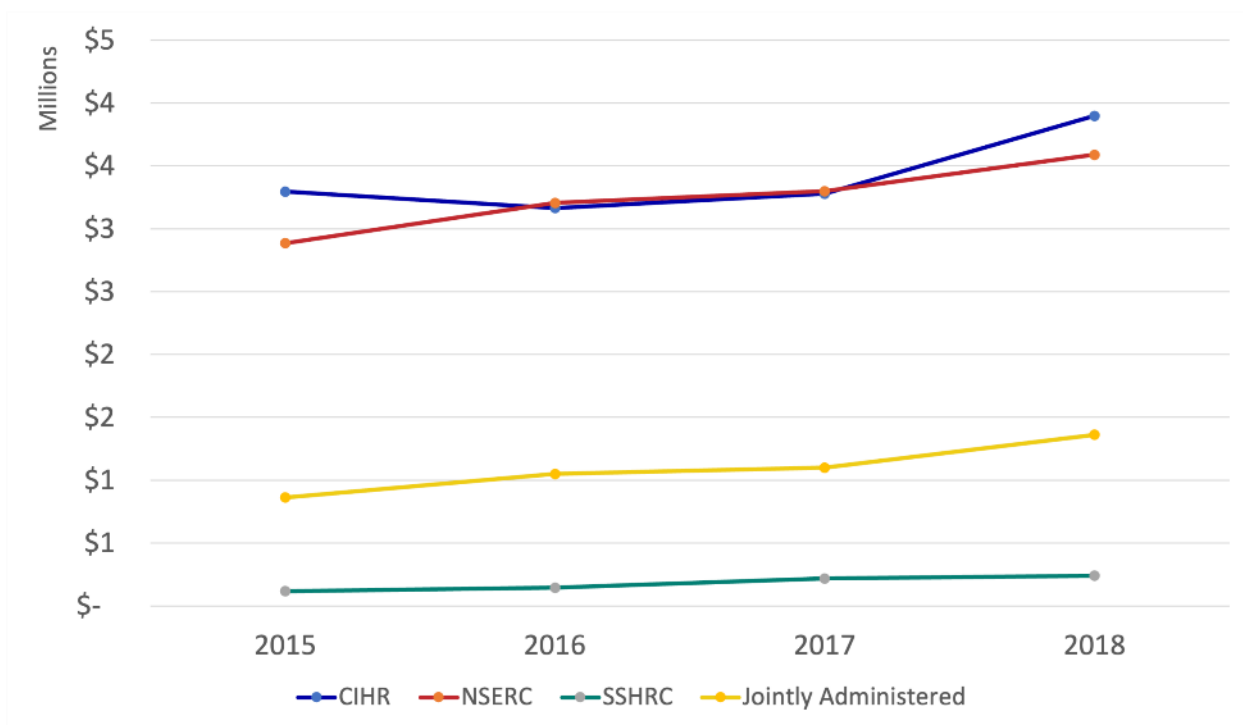


Figure 3. Total amount of hybrid and gold APCs for each Tri-Agency funder per year (2015-2018)

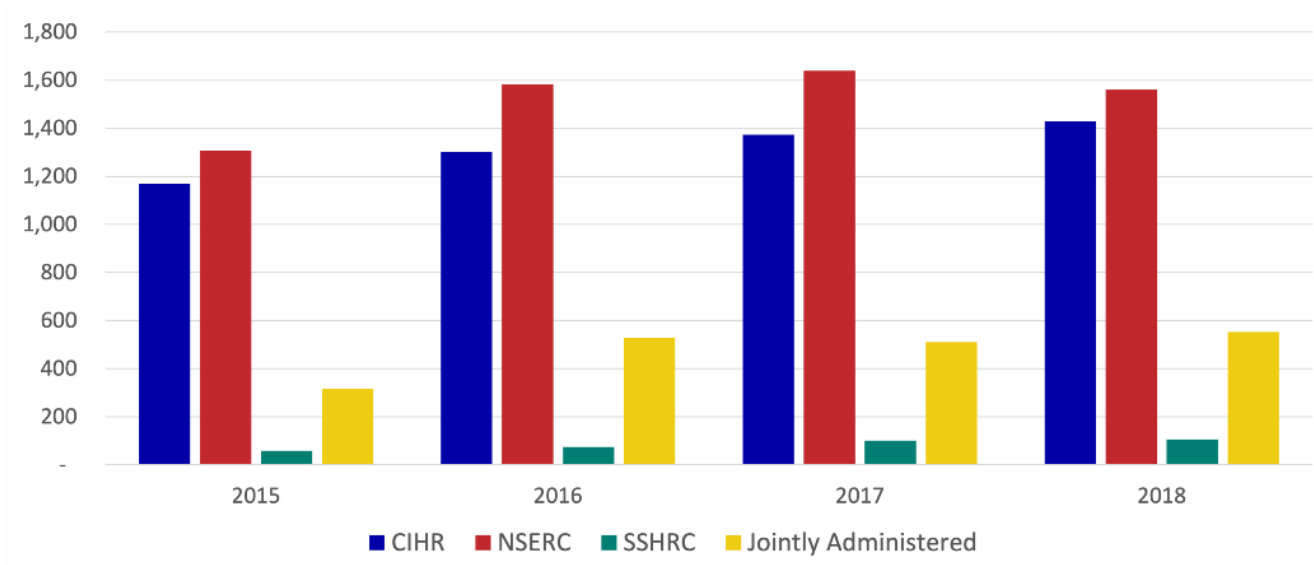


Figure 4. Number of oligopoly hybrid and gold publications per year (2015-2018)

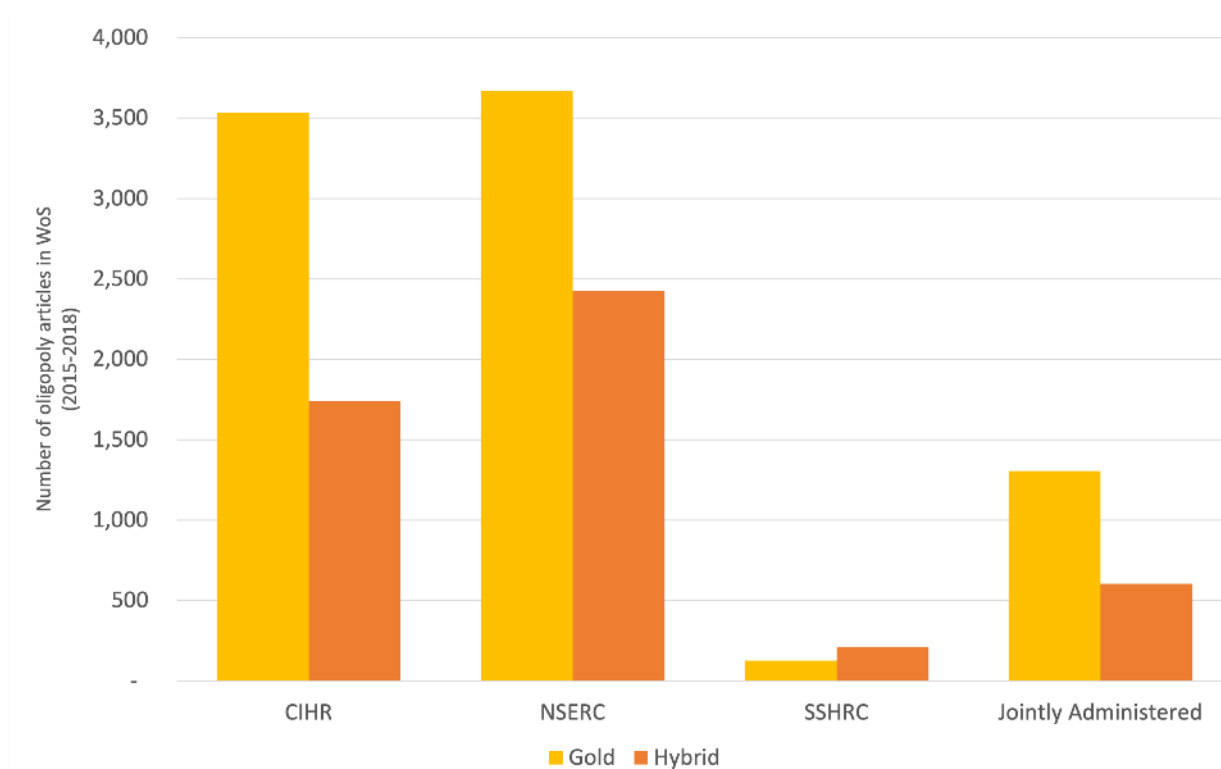


Figure 5. Number of oligopoly hybrid and gold publications (2015-2018)

4.4 APCs by Oligopoly Publisher and Funder

For any Tri-Agency publication, the largest amount of OA fees was obtained by Springer-Nature (\$11.4 million), followed by Elsevier (9.4 million), Wiley (\$3.4 million), Taylor & Francis (\$731.2k), and Sage (\$355.1k). When analyzing APC amounts per funder, we similarly find that Springer-Nature obtained the most compared to the other four publishers, with CIHR paying \$6.6 million, NSERC \$5.4 million, SSHRC \$243.4k and for jointly administered grants \$2.1 million (see Figure 6). In fact, like the overall global trend, each Tri-Agency funder paid Elsevier the second most, followed by Wiley, Taylor & Francis, and Sage (see Figure 6). This trend is also observed for all publications at the Canadian level (see Table 8).

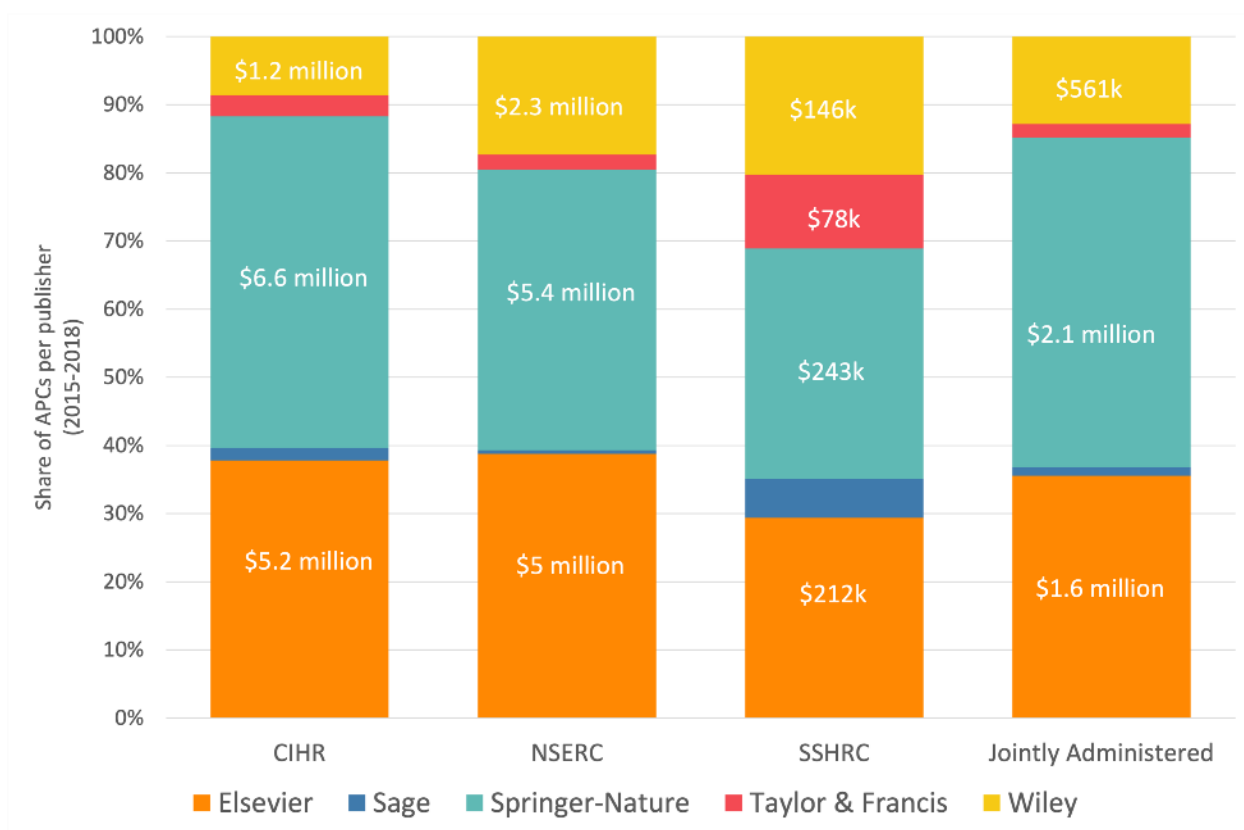


Figure 6. APCs per oligopoly publisher per funder (2015-2018)

Table 9. Share of APCs per publisher, for Canada and for any Tri-Agency funder

Total hybrid and gold APCs	All Canadian	Any Tri-Agency
Elsevier	\$23,632,166	\$9,408,728
Sage	\$1,083,276	\$355,056
Springer-Nature	\$27,065,068	\$11,358,534
Taylor & Francis	\$2,157,599	\$731,153
Wiley	\$9,332,130	\$3,452,100
All oligopoly publishers	\$63,270,240	\$25,305,571

Table 10. Share of APCs per publisher per Tri-Agency funder

Total hybrid and gold APCs	CIHR	NSERC	SSHRC	Jointly Administered
Elsevier	\$5,154,944	\$5,031,989	\$211,650	\$1,556,306
Sage	\$249,072	\$74,037	\$40,845	\$54,694
Springer-Nature	\$6,643,422	\$5,345,894	\$243,412	\$2,118,989
Taylor & Francis	\$419,473	\$277,214	\$78,164	\$86,441
Wiley	\$1,171,121	\$2,251,053	\$145,780	\$561,160
All oligopoly publishers	\$13,638,033	\$12,980,187	\$719,851	\$4,377,590

The rates of gold and hybrid are much different per oligopoly publisher, demonstrating the distinct business strategies they employed. For example, Figure 7 illustrates Elsevier’s dominance over the four other publishers in the hybrid market, where CIHR paid \$4.1 million (80.3% hybrid; 19.7% gold), NSERC \$4.6 million (91.4%; 8.6%), SSHRC \$201.4k (95.2%; 4.8%) and for jointly administered \$1.3 million (85.3%; 14.7%). Here, we see that for Elsevier, the share of hybrid publications per funder was significantly higher compared to gold, especially for SSHRC, followed closely by NSERC.

Figure 8 shows that Springer-Nature focused their business strategies on the gold OA market, where they obtained the most APCs compared to the other four publishers. CIHR paid Springer-Nature more than the other funders for gold APCs, at an estimated \$5.9 million (88.4% gold; 11.6% hybrid), followed by NSERC at \$4.6 million (85.9%; 14.1%), and jointly administered \$1.9 million (88.0%; 12.0%). In comparison, SSHRC directed the lowest amount to Springer-Nature at \$133.2k but has a more distinct portfolio with this publisher where their share is more evenly distributed between gold (54.7%) and hybrid (45.3%) than CIHR or NSERC. This differs quite a bit from SSHRC’s trends in the hybrid market with Elsevier.

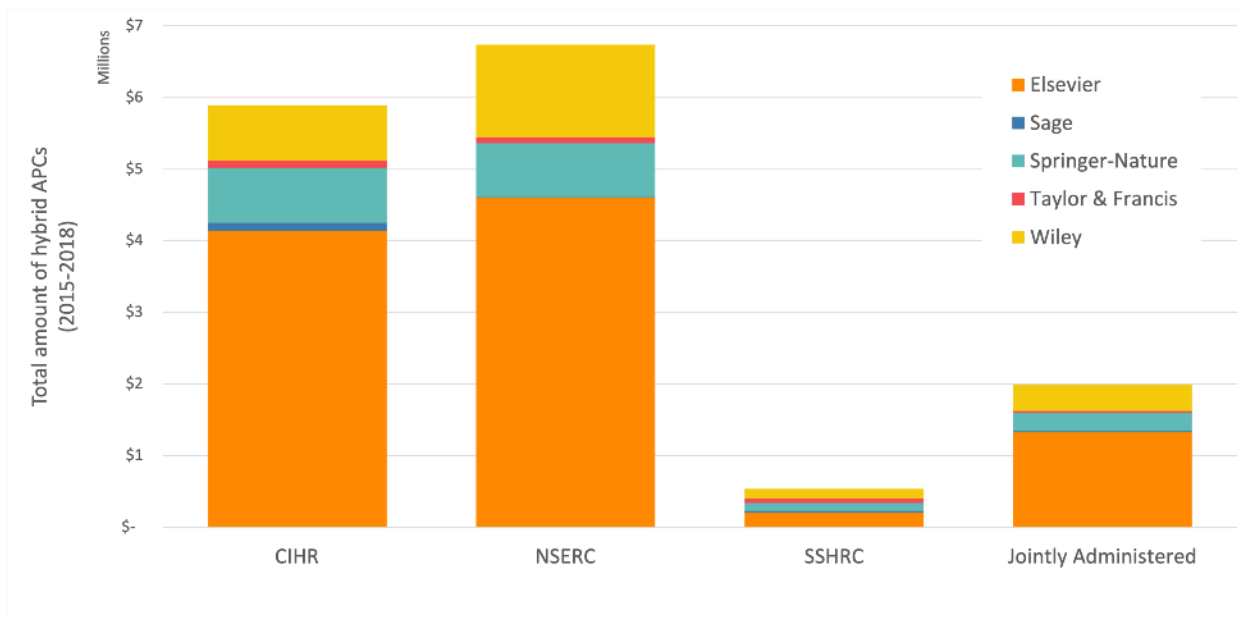


Figure 7. Total hybrid APCs per publisher per funder (2015-2018)

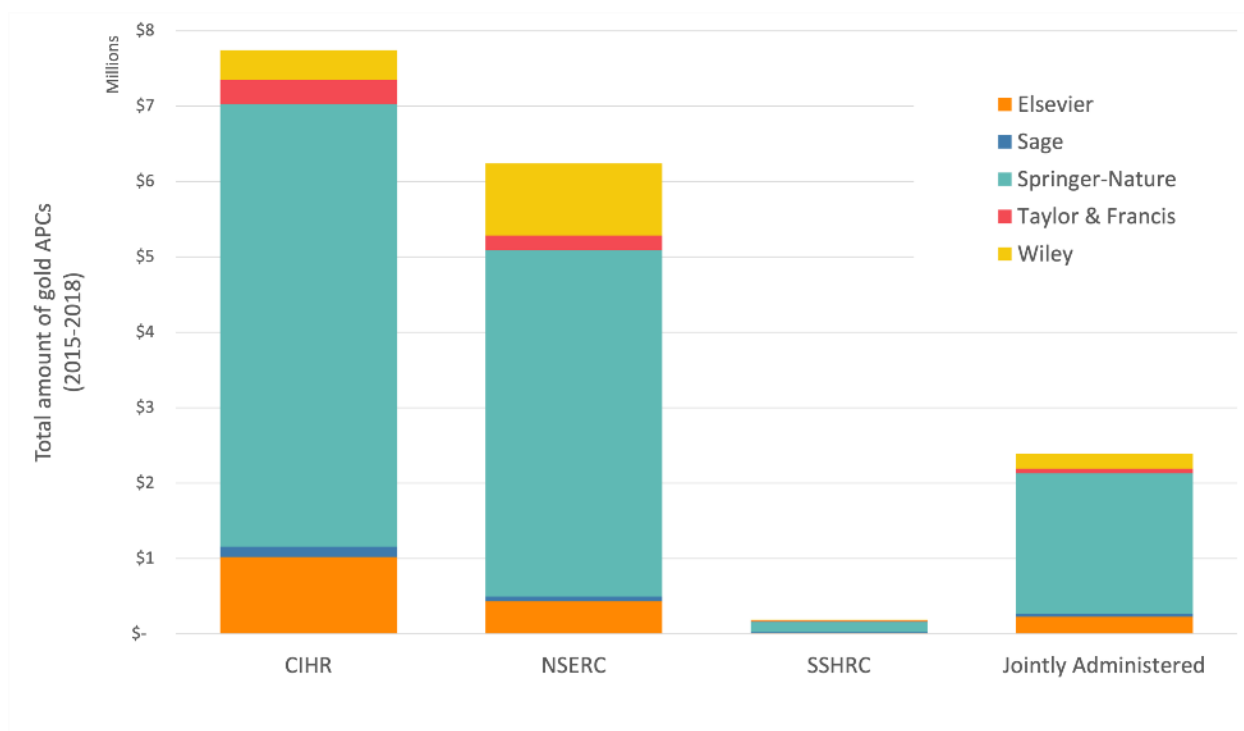


Figure 8. Total gold APCs per publisher per funder (2015-2018)

4.5 APCs per Journal

When analyzing the amount of APCs paid to the oligopoly by authors who acknowledge Tri-Agency funding on the journal level, the highest totals were obtained by Springer-Nature gold journals (see Figure 9). From 2015 to 2018, we estimate that *Nature Communications* and *Scientific Reports* obtained the highest amount in APCs from any Tri-Agency publication (\$2.6 million; \$2.1 million respectively; Figure 9), for CIHR (\$1.3 million; \$922.6k; Figure 10), NSERC (\$1.6 million; \$1.4 million; Figure 11), and for jointly administered grants (\$637.1k; \$402.7k; Figure 13). As shown in Figure 13, SSHRC-grantees paid the highest amount of APCs to Springer-Nature's gold journals, *BMC Public Health* (\$36k) and *Scientific Reports* (\$31.8k). Figures 9-13 demonstrate that the top two Springer-Nature journals per Tri-Agency funder generated a significantly higher amount of APCs, which can be explained by both the higher number of articles Tri-Agency grantees published in each journal and the journal's average APC per article. For example, between 2015 and 2018, CIHR grantees published 578 articles in *Nature Communications* and 1,442 in *Scientific Reports*, while they only published 183 articles in the journal with the third highest APC amount *Cell Reports* (\$440.0k). This correlation between publication volume and APC amount similarly occurred for any Tri-Agency, NSERC, SSHRC, and jointly administered grants. However, high publication volume was not the only factor that influenced high APC revenue at the journal level. For *Nature Communications*, the journal also charged a high APC (\$4,450), helping to increase revenues despite the journal's lower publication numbers compared to *Scientific Reports*. For example, CIHR-grantees published less than twice the number of articles in *Nature Communications* than *Scientific Reports*, but *Nature Communications* ranks first because its average APC is more than double *Scientific Reports* (\$1,435) (see Table 9).

The Tri-Agency funders have a unique portfolio of OA publishing amongst the oligopoly publishers. For the top 50 journals based on total APCs, CIHR (Figure 10) and NSERC grantees (Figure 11) predominantly paid more in gold and hybrid APCs to Springer-Nature and Elsevier journals than the other publishers. On the other hand, SSHRC had a more diverse portfolio, with more APCs paid to Wiley and Taylor & Francis, associated with their presence in SSHRC's top 50 journals based on APCs (Figure 12). Among the top 50 journals based on total APCs, we find that for any Tri-Agency acknowledged publication, 24 (48.0%) were published in gold journals. These 24 gold journals produced a far higher publication volume (n=3,667) than the top 50 hybrid journals (n=999). However, the average hybrid APC for these top 50 journals is much higher (see Table 9).

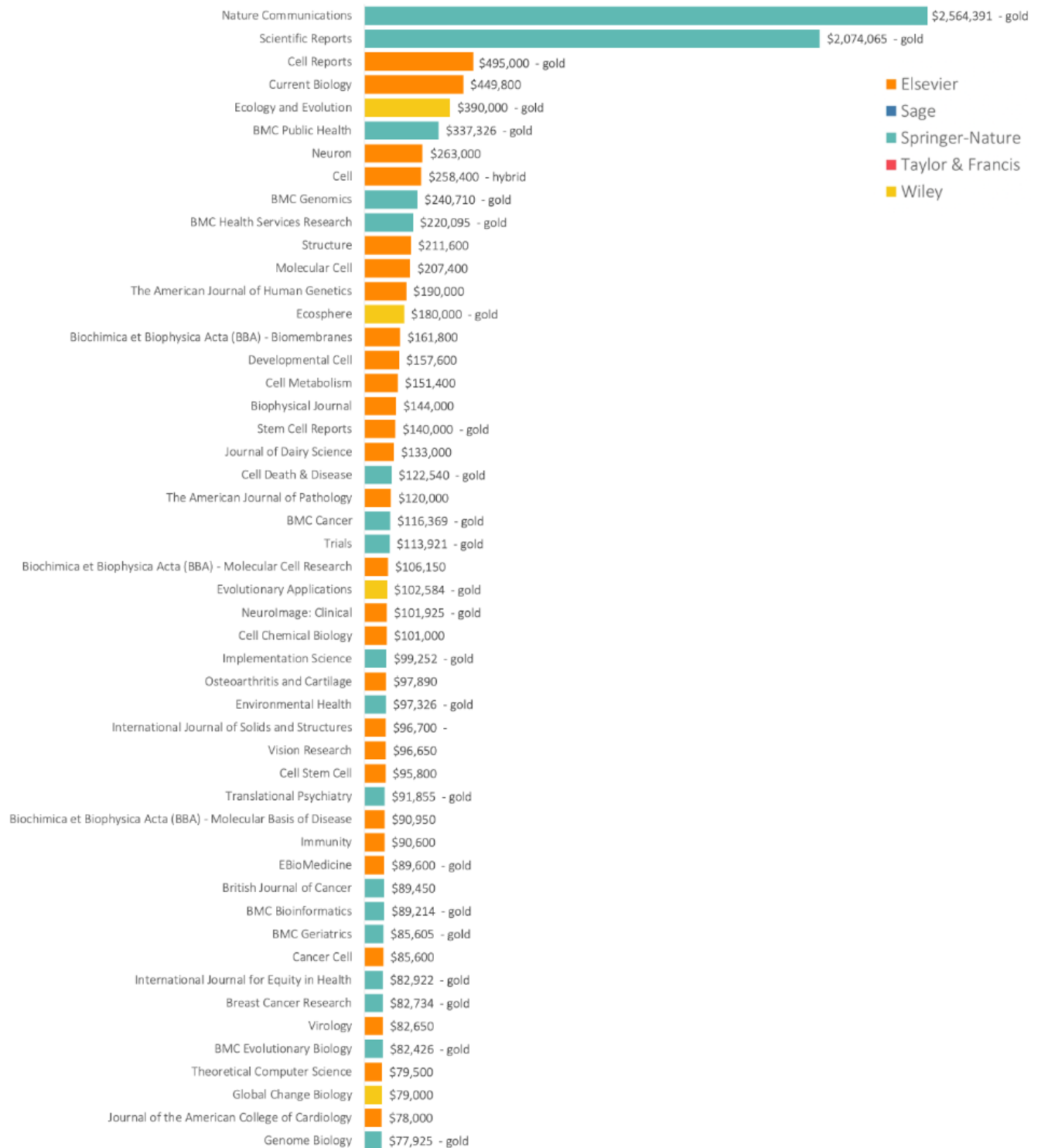


Figure 9. Total APC (gold and hybrid) per journal for Any Tri-Agency-acknowledged publication

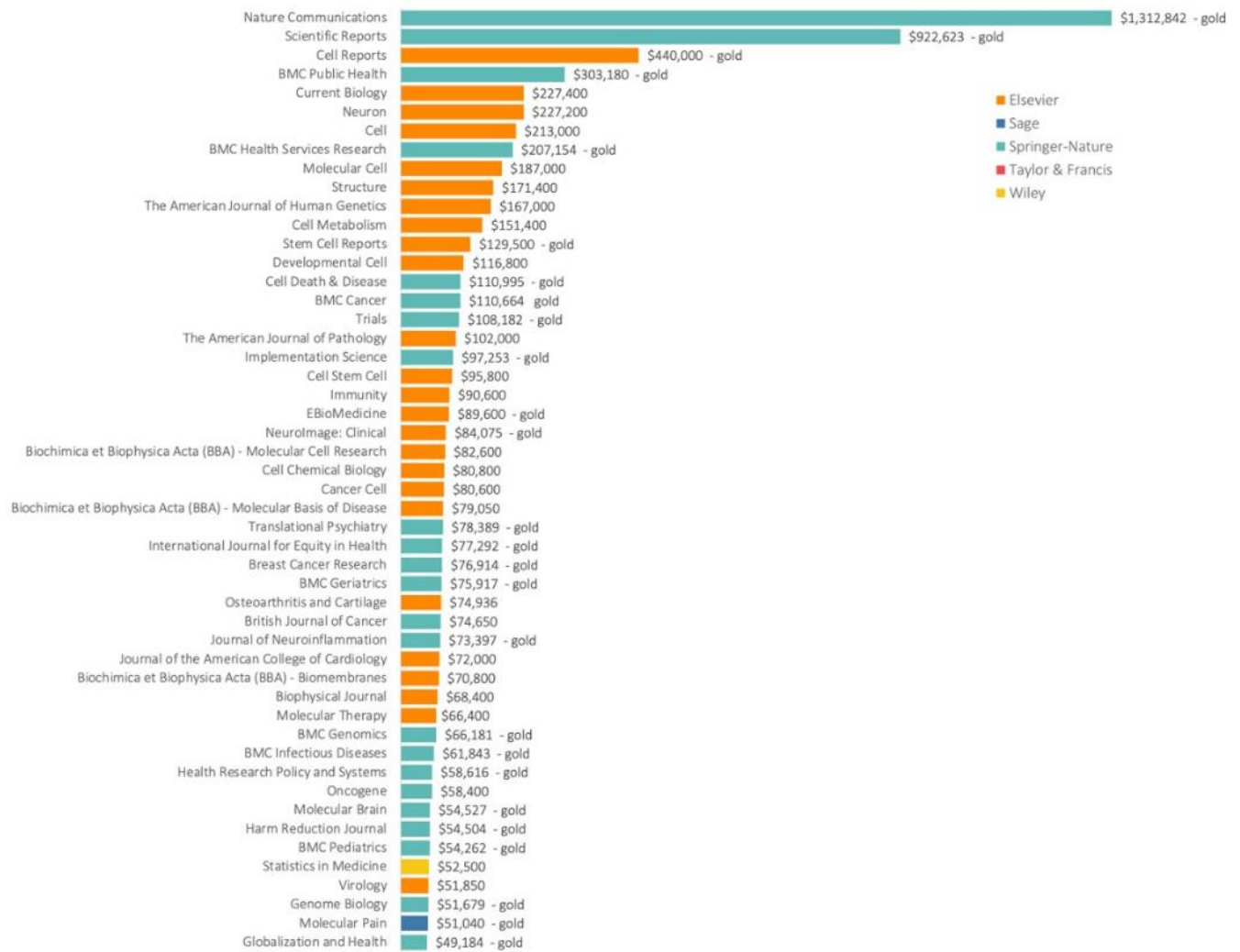


Figure 10. Total APC (gold and hybrid) per journal for CIHR-acknowledged publications

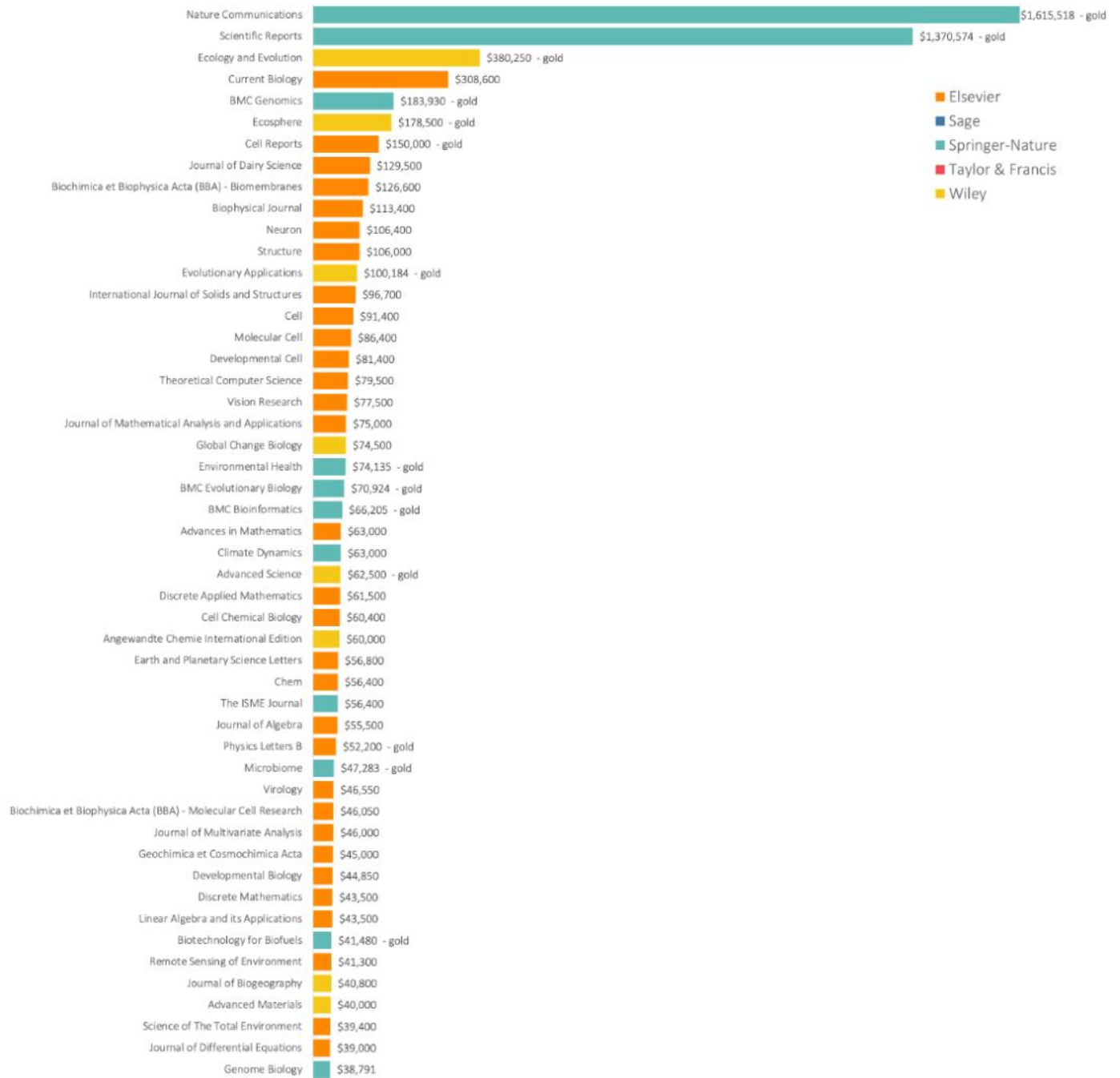


Figure 11. Total APC (gold and hybrid) per journal for NSERC-acknowledged publications

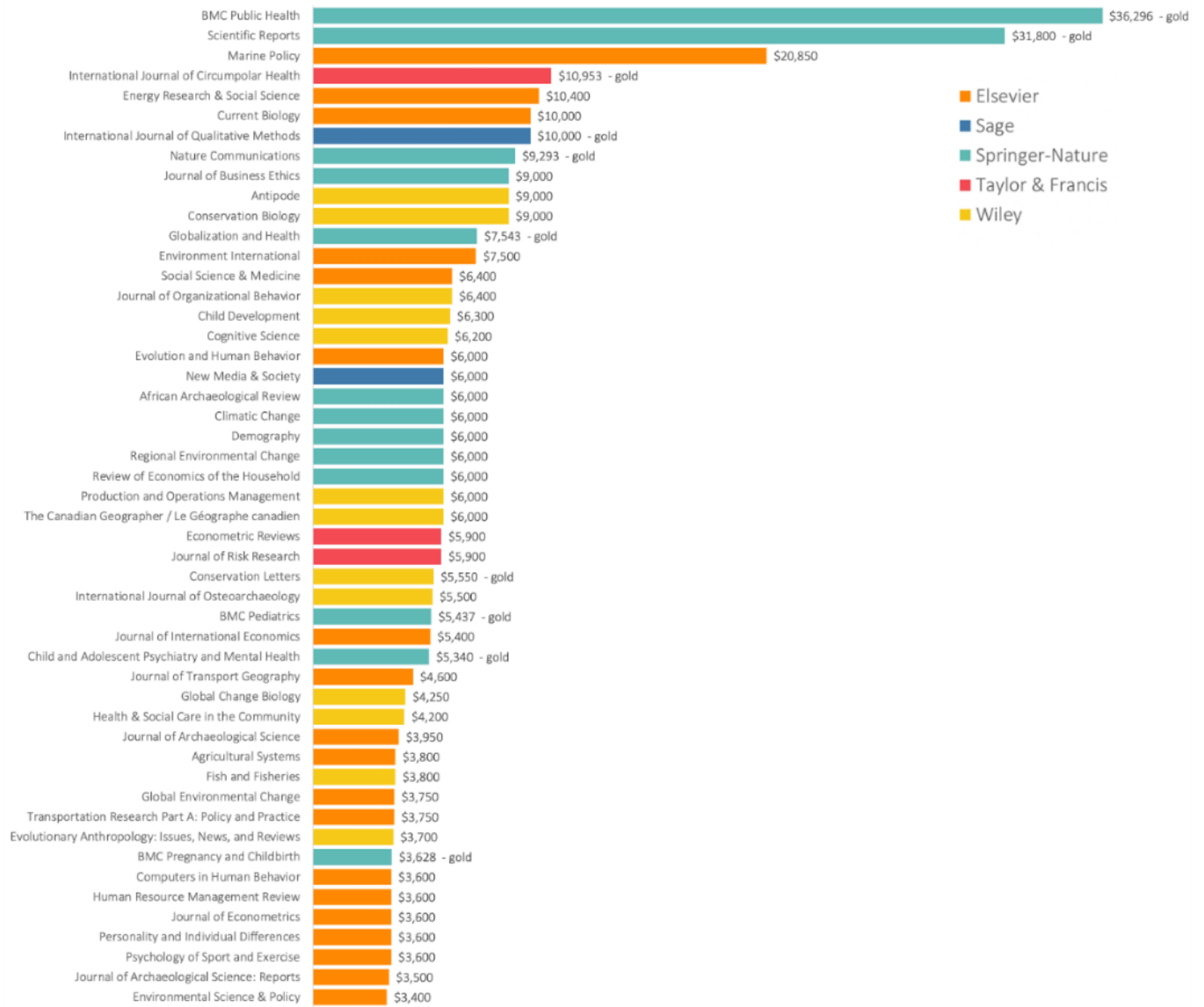


Figure 12. Total APC (gold and hybrid) per journal for SSHRC-acknowledged publications

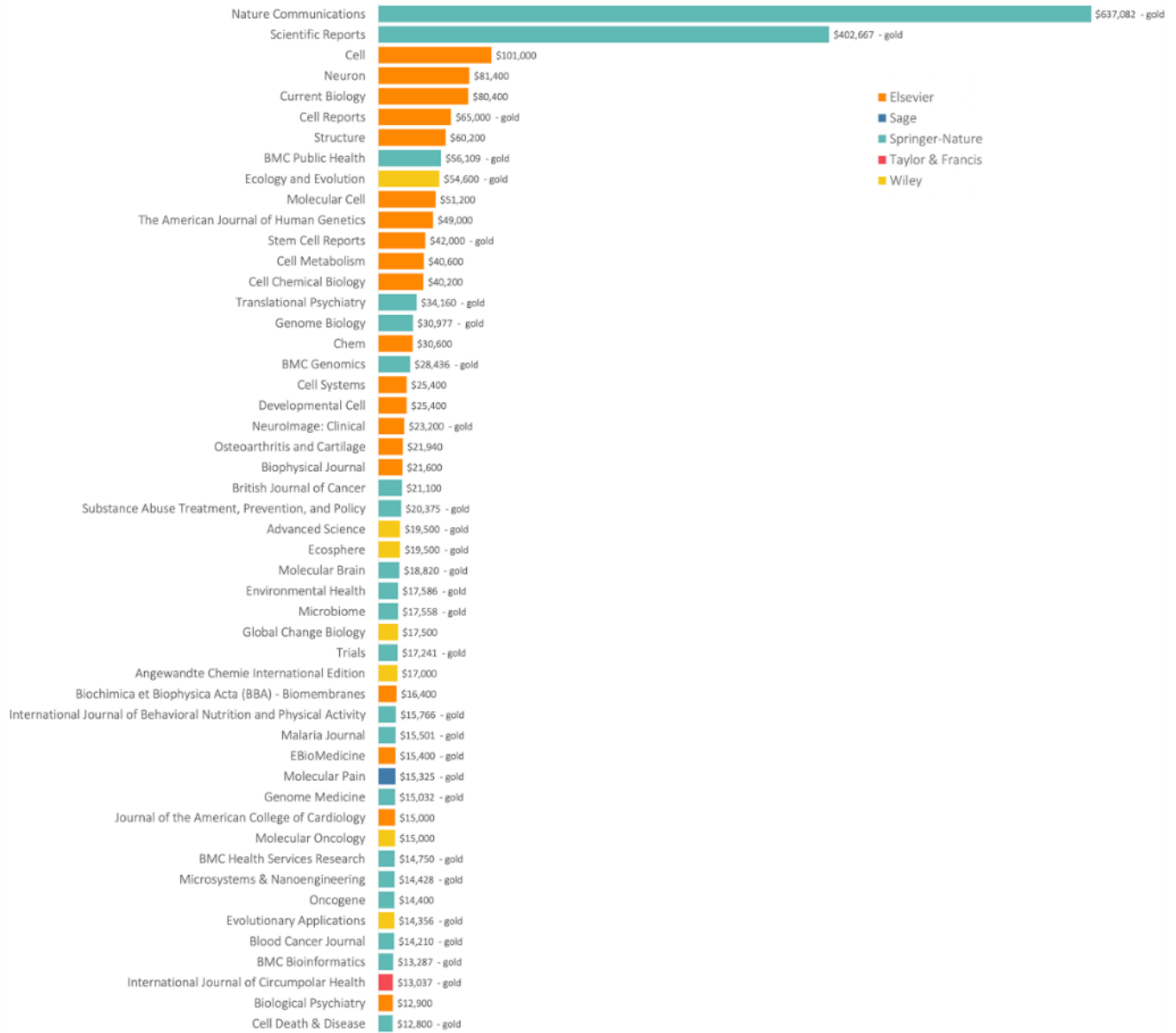


Figure 13. Total APC (gold and hybrid) per journal for publications that acknowledge jointly administered grants

Table 11. Top 10 Journals with the highest APC revenue and their associated publication volume and average APC per Tri-Agency funder

Any Tri-Agency Funder					
Publisher	Journal	OA type	Number of OA papers (gold+hybrid)	Total APC (gold+hybrid)	Average APC
Springer-Nature	Nature Communications	gold	578	\$2,564,391	\$4,437
Springer-Nature	Scientific Reports	gold	1442	\$2,074,065	\$1,438
Elsevier	Cell Reports	gold	204	\$495,000	\$2,426
Elsevier	Current Biology	hybrid	89	\$449,800	\$5,054
Wiley	Ecology and Evolution	gold	200	\$390,000	\$1,950
Springer-Nature	BMC Public Health	gold	177	\$337,326	\$1,906
Elsevier	Neuron	hybrid	52	\$263,000	\$5,058
Elsevier	Cell	hybrid	51	\$258,400	\$5,067
Springer-Nature	BMC Genomics	gold	127	\$240,710	\$1,895
Springer-Nature	BMC Health Services Research	gold	116	\$220,095	\$1,897
CIHR					
Publisher	Journal	OA type	Number of OA papers (gold+hybrid)	Total APC (gold+hybrid)	Average APC
Springer-Nature	Nature Communications	gold	295	\$1,312,842	\$4,450
Springer-Nature	Scientific Reports	gold	643	\$922,623	\$1,435
Elsevier	Cell Reports	gold	183	\$440,000	\$2,404
Springer-Nature	BMC Public Health	gold	159	\$303,180	\$1,907
Elsevier	Current Biology	hybrid	45	\$227,400	\$5,053
Elsevier	Neuron	hybrid	45	\$227,200	\$5,049
Elsevier	Cell	hybrid	42	\$213,000	\$5,071
Springer-Nature	BMC Health Services Research	gold	109	\$207,154	\$1,900
Elsevier	Molecular Cell	hybrid	37	\$187,000	\$5,054
Elsevier	Structure	hybrid	34	\$171,400	\$5,041
NSERC					
Publisher	Journal	OA type	Number of OA papers (gold+hybrid)	Total APC (gold+hybrid)	Average APC
Springer-Nature	Nature Communications	gold	365	\$1,615,518	\$4,426
Springer-Nature	Scientific Reports	gold	952	\$1,370,574	\$1,440
Wiley	Ecology and Evolution	gold	195	\$380,250	\$1,950
Elsevier	Current Biology	hybrid	61	\$308,600	\$5,059
Springer-Nature	BMC Genomics	gold	97	\$183,930	\$1,896
Wiley	Ecosphere	gold	119	\$178,500	\$1,500

Elsevier	Cell Reports	gold	62	\$150,000	\$2,419
Elsevier	Journal of Dairy Science	hybrid	37	\$129,500	\$3,500
Elsevier	Biochimica et Biophysica Acta (BBA) - Biomembranes	hybrid	39	\$126,600	\$3,246
Elsevier	Biophysical Journal	hybrid	63	\$113,400	\$1,800
SSHRC					
Publisher	Journal	OA type	Number of OA papers (gold+hybrid)	Total APC (gold+hybrid)	Average APC
Springer-Nature	BMC Public Health	gold	19	\$36,296	\$1,910
Springer-Nature	Scientific Reports	gold	22	\$31,800	\$1,445
Elsevier	Marine Policy	hybrid	10	\$20,850	\$2,085
Taylor & Francis	International Journal of Circumpolar Health	gold	6	\$10,953	\$1,826
Elsevier	Energy Research & Social Science	hybrid	4	\$10,400	\$2,600
Elsevier	Current Biology	hybrid	2	\$10,000	\$5,000
Sage	International Journal of Qualitative Methods	gold	9	\$10,000	\$1,111
Springer-Nature	Nature Communications	gold	2	\$9,293	\$4,647
Springer-Nature	Journal of Business Ethics	hybrid	3	\$9,000	\$3,000
Wiley	Antipode	gold	3	\$9,000	\$3,000
Jointly administered					
Publisher	Journal	OA type	Number of OA papers (gold+hybrid)	Total APC (gold+hybrid)	Average APC
Springer-Nature	Nature Communications	gold	144	\$637,082	\$4,424
Springer-Nature	Scientific Reports	gold	282	\$402,667	\$1,428
Elsevier	Cell	hybrid	20	\$101,000	\$5,050
Elsevier	Neuron	hybrid	16	\$81,400	\$5,088
Elsevier	Current Biology	hybrid	16	\$80,400	\$5,025
Elsevier	Cell Reports	gold	36	\$65,000	\$1,806
Elsevier	Structure	hybrid	12	\$60,200	\$5,017
Springer-Nature	BMC Public Health	gold	30	\$56,109	\$1,870
Wiley	Ecology and Evolution	gold	28	\$54,600	\$1,950
Elsevier	Molecular Cell	hybrid	10	\$51,200	\$5,120

4.6 Average APCs

For all publications acknowledging any Tri-Agency funding, the average APC based on articles was \$1,904 for gold OA articles and \$2,973 for hybrid OA articles from 2015 to 2018 (see Table 9). On average, hybrid APCs were therefore 56.1% more expensive than gold articles. CIHR grantees paid more on average than the other funders, at \$2,191 for gold and \$3,390 for hybrid across the four years analyzed, followed by the jointly administered grants, NSERC, and then SSHRC (see Table 10). For CIHR, NSERC, and the jointly administered grants, the highest APC was \$5,200 for gold and hybrid journals; SSHRC paid a maximum of \$5,000 for the hybrid journal *Current Biology*. *Nature Communications* was the only gold OA journal that charged \$5,200. However, there were various hybrid journals that charged the same fee, especially for CIHR's publications in Elsevier's top journals (see Table 9). When breaking down averages at the journal level per publisher, Wiley had the highest APCs for gold and hybrid, except for CIHR who paid Elsevier on average a higher APC at \$2,377 for gold and \$3,460 for hybrid (see Table 11-15).

Table 12. Overall average APCs by Tri-Agency funder from 2015 to 2018

	Gold			Hybrid		
	N	Average APC	Max APC	N	Average APC	Max APC
Any Tri-Agency	6,892	\$1,904	\$5,200	4,097	\$2,973	\$5,200
CIHR	3,534	\$2,191	\$5,200	1,739	\$3,390	\$5,200
NSERC	3,668	\$1,701	\$5,200	2,424	\$2,780	\$5,200
SSHRC	126	\$1,468	\$5,200	211	\$2,535	\$5,000
Jointly Administered	1,306	\$1,829	\$5,200	604	\$3,293	\$5,200

Table 13. Average APCs for any Tri-Agency funder per oligopoly publisher (2015 to 2018)

	Hybrid+Gold	Hybrid	Gold
Elsevier	\$2,627	\$2,868	\$1,717
Sage	\$1,775	\$2,796	\$1,378
Springer-Nature	\$2,020	\$3,089	\$1,916
Taylor & Francis	\$2,222	\$2,932	\$1,987
Wiley	\$2,751	\$3,378	\$2,124
All oligopoly publishers	\$2,303	\$2,973	\$1,904

Table 14. Average APCs for CIHR per oligopoly publisher (2015 to 2018)

	Hybrid+Gold	Hybrid	Gold
Elsevier	\$3,174	\$3,460	\$2,377
Sage	\$1,993	\$2,746	\$1,625
Springer-Nature	\$2,238	\$3,185	\$2,155
Taylor & Francis	\$2,411	\$2,950	\$2,280
Wiley	\$3,066	\$3,422	\$2,544
All oligopoly publishers	\$2,586	\$3,390	\$2,191

Table 15. Average APCs for NSERC per oligopoly publisher (2015 to 2018)

	Hybrid+Gold	Hybrid	Gold
Elsevier	\$2,337	\$2,612	\$1,102
Sage	\$1,722	\$2,500	\$1,642
Springer-Nature	\$1,838	\$3,006	\$1,729
Taylor & Francis	\$2,038	\$2,898	\$1,815
Wiley	\$2,642	\$3,404	\$2,026
All oligopoly publishers	\$2,131	\$2,780	\$1,701

Table 16. Average APCs for SSHRC per oligopoly publisher (2015 to 2018)

	Hybrid+Gold	Hybrid	Gold
Elsevier	\$2,035	\$2,055	\$1,708
Sage	\$1,201	\$2,833	\$614
Springer-Nature	\$2,117	\$2,900	\$1,730
Taylor & Francis	\$2,299	\$2,950	\$1,247
Wiley	\$2,916	\$3,019	\$1,986
All oligopoly publishers	\$2,136	\$2,535	\$1,468

Table 17. Average APCs for Jointly Administered grants per oligopoly publisher (2015 to 2018)

	Hybrid+Gold	Hybrid	Gold
Elsevier	\$2,769	\$3,320	\$1,409
Sage	\$1,709	\$2,833	\$1,450
Springer-Nature	\$1,958	\$3,132	\$1,863
Taylor & Francis	\$2,336	\$2,950	\$2,139
Wiley	\$2,849	\$3,368	\$2,219
All oligopoly publishers	\$2,292	\$3,293	\$1,829

5. DISCUSSION

This study demonstrates the continued growth in the OA market, as APCs paid by grantees that acknowledge Tri-Agency funding to five for-profit academic publishers (Elsevier, SAGE, Springer-Nature, Taylor & Francis, Wiley), which have been identified as the oligopoly of academic publishers. Although OA policies enable access to research funded by public tax dollars, ideally ensuring science remains a public good, the APC model creates barriers and inequities by limiting access to only those who can afford to pay their price tag. To make articles available OA, many authors pay APCs, often using grant funds to cover these fees. The use of these grant funds not only diverts money away from research to support the revenues of commercial publishers but also exacerbates inequities in the research system since only those who have access to funding can pay fees (Olejniczak & Wilson, 2020; Siler & Frenken, 2020; SSHRC, 2020b).

This study estimates that authors who acknowledge Tri-Agency funding paid the oligopoly of publishers \$25.3 million for gold and hybrid articles in the four-year period from 2015 to 2018. This estimate is restricted to the five oligopoly publishers and therefore not a comprehensive estimate of the total amount of APCs paid by Tri-Agency grantees to all publishers, as we avoid many OA publishers like Frontiers, Hindawi, MDPI, and PLOS, previously identified as major players in OA publishing (Butler et al., 2022b; Khoo, 2019; Zhang et al., 2022). Nevertheless, this study focuses on the oligopoly since they dominate half of the scholarly market (Larivière et al., 2015), which our results also indicate since 49.8% of OA publications by authors who acknowledge the tri-agencies are published by an oligopoly publisher.

The \$25.3 million of Tri-Agency funding paid for APCs to the oligopoly suggests these publishers have secured themselves in the OA market while continuing to profit from the traditional subscription model (Holley, 2018). For example, in 2022, CRKN calculates that its members paid \$73.2 million of a total listed \$85.4 million in annual subscription costs to the oligopoly (\$5.5 million to Sage is part of a transformative agreement) (CRKN, 2022). Our study does not calculate the total amount paid by subscriptions, but we find that between 2015-2018, 61.4% of Tri-Agency articles published by the oligopoly were closed (CIHR=44.3%; NSERC=66.4%; SSHRC=74.1%). Previous studies also found a similar rate of closed articles for the Tri-Agencies (Larivière & Sugimoto, 2018; Paquet et al., 2022). This volume of paywalled articles compared to gold and hybrid serves to highlight the significant amount of revenue the oligopoly extracts from public tax dollars, through journal subscription costs paid by university libraries with provincial funds. It is important to monitor the oligopoly's shift to the OA market as these publishers establish strategies to enhance the possible loss of subscription revenues in light of increasing pressure to publish OA through initiatives like Plan S and the OSTP memorandum.

We find that overall, CIHR published the highest volume of OA compared to NSERC and SSHRC, at 64.7% (n=18,462) for oligopoly or non-oligopoly articles, which corroborates previous studies (Larivière & Sugimoto, 2018; Paquet et al., 2022). Paquet et al. (2022) resist attributing the higher rate of OA for CIHR as a sign of higher OA practices for the health sciences, explaining the challenge to disentangle the influence of funder and field culture, as well as international collaborations. Nevertheless, the difference in overall OA rates across the three funders points to disciplinary differences, where such factors as a discipline's publishing practices may influence their rates of OA. For example, the SSH disciplines continue to publish books and monographs, which are not included in this study as we rely on journal articles to estimate OA fees. Similarly,

Solomon and Björk (2016) explain that the SSH is underrepresented in the APC market because of their lack of APC-funded OA journals. Each Tri-Agency's volume of OA outputs for the years analyzed influences the calculation of APC totals paid to the oligopoly since a higher publication volume correlates with higher overall APC revenues.

This study finds that Tri-Agency grantees have paid a significant amount of money for OA articles to the oligopoly between 2015-2018. Such high revenues indicate these five publishers use their dominance in the traditional market to quickly establish themselves as leaders in the emerging OA market in the face of competition from new players such as PLOS, MDPI, Frontiers, and others. The oligopoly can assert their power in the OA market since they have an established history as top publishers and dominance in the overall market (Larivière et al., 2015). A recent study that examined the consolidation of the scholarly market found that, although there was less consolidation at the time of their study, the largest publishers nevertheless increased their share in 2021, demonstrating a concentrated control within the market (Pollock, 2022). The market dominance of publishers like the five oligopoly publishers led academic institutions to pay unsustainable costs for subscriptions (Khelifaoui & Gingras, 2020). Now, we see those publishers leveraging their control in the OA market where they drive market pricing for APCs. Publishers rely on the name brand of their journals to sell their product, where authors pay high APCs to publish in what are deemed prestigious journals (Brembs, 2017; Khelifaoui & Gingras, 2020; Khoo, 2019; Shu et al., 2018; Siler et al., 2020). Studies have shown that authors lack price sensitivity when selecting their journals, valuing prestige over the amount of the APC (Björk & Solomon, 2015; Brembs, 2017; Budzinski et al., 2020; Khoo, 2019; Morrison et al., 2021b). Similarly, Schönfelder (2020) found a correlation between APCs and journal reputation, but more so for gold than hybrid journals, where APCs are mirroring the journal's citation impact.

The results demonstrate that Springer-Nature, Elsevier, and Wiley, dominate the OA market over Sage and Taylor & Francis in terms of article volume and associated revenues for gold and hybrid APCs. The difference between top and bottom producers is quite vast. For the Tri-Agencies, Springer-Nature published 5,624 articles and \$11,358,534 in revenues, compared with Sage, the bottom, at 200 articles and \$355,056 in revenues. Although Wiley produced fewer articles (n=1,255) than Springer-Nature and Elsevier, they charge, on average, a higher APC for both gold and hybrid articles, offsetting their lower production volume but securing their place as a top producer. At the global level, Taylor & Francis and Sage similarly own a smaller piece of the market, where they only account for 7.2% and 3.0% of the \$1.06 billion of APC revenue (Butler et al., 2022b). In this way, these two oligopoly publishers show less market power compared to Springer-Nature, Elsevier, and Wiley. Nevertheless, Sage and Taylor & Francis wield a high level of control in the larger picture of all publishers as Zhang et al. (2022) find they rank fourth and sixth (respectively) in their list of top 12 publishers, and Crawford (2022) finds they rank tenth and seventh (respectively) amongst the top eleven publishers in the DOAJ.

This study finds that for Tri-Agency publications, Springer-Nature draws 86.4% of their revenues from gold articles over hybrid, a finding similarly noted for CIHR (88.4%) and NSERC (85.9%). Springer-Nature leading in terms of OA volume and total APCs mirrors the larger global trend (Butler et al., 2022b) and corroborates previous studies (Crawford, 2021; Rodrigues et al., 2020; Zhang et al., 2022). For example, Rodrigues et al. (2020) found that Springer-Nature is responsible for 35% of the journals indexed in DOAJ, which represents an even larger share than in traditional publishing. Springer-Nature's strategy is to acquire well-established OA publishers and journals and increase their market share of articles through new or spin-off journals (Khelfaoui & Gingras, 2020, 2022; Rodrigues et al., 2020). For example, between 1992 and 2020 34 *Nature* derivatives

(e.g., *Nature Genetics*, *Nature Ecology and Evolution*) were founded (Khelifaoui & Gingras, 2022). The derivative *Nature Communications* is the OA journal with the highest APC sum in our dataset. Another example of Springer-Nature's market strategy includes their 2008 acquisition of *BioMed Central (BMC)*, a prominent and large OA publisher with more than 300 journals (BMC, 2022). Jahn and Tullney (2016) found that most APC fees for German institutions were spent on Springer-Nature journals, possibly owing to their merger with BMC and other publishers like Springer Science + Business Media and Nature Publishing Group in 2015. Asai (2019) found that BMC sets higher APCs for their more frequently cited journals, and charges a lower APC for newly launched titles, an example of price discrimination and pricing based on prestige and established brand name.

The two journals, which are both gold, that generate the highest revenues are both published by Springer-Nature: the large multidisciplinary journal *Nature Communications*, accounting for \$2.6 million, followed by the mega journal *Scientific Reports*, at \$2.1 million. Springer-Nature's focus on acquiring prominent OA journals like BMC and continuing to grow such mega journals like *Scientific Reports* secures their dominance in the OA market, owing both to the overall volume of articles these journals produce, and the high APC average (\$4,437) for *Nature Communications*. Khelifaoui and Gingras (2022) describe Springer-Nature's strategy with *Nature* journals as a transfer pyramid, where rejected manuscripts are transferred from the most prestigious and selective journal, *Nature*, to less prestigious OA journals like *Nature Communications*, located in the middle, and *Scientific Reports* on the bottom. Despite their focus on gold OA, Springer-Nature also generated \$1.5 million from hybrid APCs for Tri-Agency acknowledged publications, demonstrating their dominance in the overall OA market.

While Springer-Nature focused on gold, Elsevier focused on the hybrid market, with 86.3% (n=2,833) of Tri-Agency articles published as hybrid, correlating with \$8.1 million in revenues, compared to a total of 13.7% (n=748) gold articles, generating \$1.3 million. Jahn et al. (2022) find that the number of hybrid articles for Elsevier is doubling each year, and its share continuing to increase. This demonstrates their continued investment in the traditional market, where they draw revenues from subscriptions and APCs. Aspesi et al.'s (2019) analysis of the scholarly market indicated that Elsevier made more in journal revenue than any other publisher, including Springer-Nature, indicating that Elsevier relies on drawing revenues outside the OA market. Crawford (2021) found that between 2015 to 2020, Elsevier ranks lower than Springer-Nature in terms of revenues and volume of articles for gold OA. Although findings demonstrate Elsevier's focus on hybrid, they nevertheless continue to draw revenues from gold. We find that Elsevier's gold journal, *Cell Reports*, ranks third overall in terms of overall journal revenue, at \$495.0k.

According to the FOAA, APCs of no more than \$50 per page and \$1,000 per article are feasible to sustain the costs to publish OA (FOAA, 2022). Factoring in differences between journals' rejection rates, staffing, editorial services, and publishing volume, Grossman and Brembs (2021) similarly estimate 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 even 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. Even more, Schönfelder (2020) found that in the DOAJ, it is large commercial publishers who charge higher APCs than small for-profit publishers. We find that grantees funded by the Tri-Agencies paid the oligopoly, on average, a higher APC than the recommended amount. For gold journals, tri-agency grantees paid on average \$1,904, and for hybrid \$2,973. These higher averages

for hybrid articles are in line with previous studies (Budzinski et al., 2020; Butler et al., 2022b; Jahn & Tullney, 2016; Morrison et al., 2015; Pinfield et al., 2016; Solomon & Björk, 2016; Zhang et al., 2022). Charging a higher APC for hybrid articles is counterintuitive since publishers draw revenue from both subscriptions and APCs, demonstrating that hybrid APCs are potentially a 100% profit margin since the publisher is already receiving revenue from the journal's subscription. Gold journals, on the other hand, are mostly funded through APCs paid by authors. The publisher's ability to set higher prices for hybrid demonstrates their market power (Budzinski et al., 2020), owing largely to their long-standing history and well-established business models (Budzinski et al., 2020; Jahn & Tullney, 2016; Laakso et al., 2011; Solomon & Björk, 2016).

CIHR grantees pay, on average, higher APCs for hybrid and gold articles, than NSERC and SSHRC. This finding is not surprising since CIHR funds medical sciences research, a field that typically pays higher APCs than the natural sciences and social studies and humanities (Klebel & Ross-Hellauer, 2022; Schönfelder, 2020; Solomon & Björk, 2012). Such price differences between STEM and SSH fields are owing to their higher rates of publishing, higher readership, and the high cost of publishing, caused by factors like professional copyediting (Siler et al., 2020, p. 52). However, it is likely that because SSH is less resourced, it restricts the pool of grant funds authors can draw from to pay APCs (Klebel & Ross-Hellauer, 2022; Schönfelder, 2020). The higher resourcing in STEM fields also attracts these large commercial publishers, who opportunistically take advantage of these funding disparities and “upscale” by publishing more prestigious journals (Siler & Frenken, 2020, p. 52). These publisher strategies respond to the capitalist system on which their model is predicated – to remain competitive and sustain a profitable business.

In terms of number of articles, the APC-based model continues to dominate OA (Siler & Frenken, 2020) at least partly due to the central role that oligopoly publishers play in this growing market. Profit and prestige represent the Western worldview on academic publishing and the reward system at large (Chan et al., 2020). A look at the publishing landscape in the Global South demonstrates that sustainable and affordable OA publishing exists outside the author-pays model (Khanna et al., 2022). More than two-thirds of OA journals indexed in the DOAJ do not charge APCs. Simard et al. (2022) show that diamond journals are more prevalent in the Global South and many low and middle-income countries, with some regions such as South America achieving nearly 100% of diamond OA through regional initiatives. Khanna et al. (2022) demonstrate the diversity in terms of geography, language, and disciplines of 25,761 OA journals run on the open-source publishing platform Open Journal Systems. The dominant APC model that prevails in the Global North commodifies knowledge and further exacerbates inequities, rather than encouraging inclusive publishing practices, as set out in BOAI 2022 (BOAI20, 2022). Funding that supports diverse publishing, like Diamond OA, and moves away from the APC model dominated by large publishers can ensure the sustainability of the scholarly system (Alperin, 2022).

6. CONCLUSION AND OUTLOOK

6.1 Summary of Findings and the Impact of OA Policies

The Canadian Tri-Agencies (CIHR, NSERC, SSHRC) published their harmonized OA Policy on Publications in 2015 to ensure that the research they fund, through public tax dollars, is openly accessible to the “widest possible audience” (Government of Canada, 2016). At the time, their policy kept pace with the growing number of funder mandates and ensured the practices of their research community aligned with international collaborators (ROARMAP, 2022). Policies reflect the unique context of each community, and therefore have varying features and guidelines, such as embargo periods or the routes to publish OA (gold, hybrid, green), to incentivize and compel compliance. These policy features exist because research is entrenched in the publishing and academic reward system and funders must consider the diverse influences on a researcher’s publishing practices, such as disciplinary culture and the freedom to choose their publication venue. OA policies, though, have unintended consequences because of this interwoven relationship between researcher, funder, publisher, and academia, who each apply varying social, economic, and political pressures on the system.

As shown in this study, one such unintended consequence of funder OA policies is the use of public tax dollars, through grant funds, to pay for APCs. This study demonstrates that paying APCs with grant funds is not the best use of public tax dollars, and research dollars if they go towards generating high profits for shareholder companies. Studies have demonstrated that APC pricing is not based on the cost to run a journal, but rather on factors like journal prestige (FOAA, n.d.; Grossmann & Brembs, 2021). Paying APCs with grant funds, then, is not promoting openness to democratize knowledge, but rather to maintain the profits of a business.

We found that between 2015 and 2018, 52.0% of articles that acknowledge the Tri-Agencies are behind paywalls and therefore not in compliance with TAOAPP. However, this percentage of closed articles increases to 61.4% when the article is published by an oligopoly publisher. This is a high percentage of articles that are inaccessible to the public, demonstrating a high non-compliance rate with the TAOAPP. Larivière and Sugimoto's (2018) study of compliance with OA policies explains the many factors that influence compliance, such as immediate deposit of articles, stricter enforcement, or dedicated infrastructure. The aim should be to increase compliance to achieve the Tri-Agency objective of societal advancement (Government of Canada, 2016). However, we should be conscious of the unintended consequences of increased rates of OA.

The ideal aim would be to increase rates of OA and ensure more literature is openly available rather than behind a paywall. However, the author-pays APC model exacerbates inequities through economic barriers. Results show that authors who acknowledge the Tri-Agencies paid \$25.3 million to the oligopoly of publishers for gold and hybrid, which made up only 20.9% of the total outputs. An increase in gold and hybrid paid by APCs could direct an exorbitant amount more grant funds toward for-profit publishers. The current system cannot sustain an increase in OA where authors, and therefore funders, pay OA fees.

6.2 Recommendations

Policies and initiatives that support the broader research community could support a more sustainable system to achieve the funder's aim in the broader dissemination of funded research. For example, funding community-driven, non-profit models, such as Diamond OA, can ensure a more equitable approach to publishing OA that promotes the local, regional, and national context.

To sustain the scholarly system, it is also essential that funding be distributed toward open science infrastructure. This means funding and supporting existing repositories, rather than reproducing national silos, and financially supporting initiatives that keep pace with global developments. A key example of supporting open science infrastructure in Canada is SSHRC's \$3 million grant to fund Coalition Publica, a non-commercial and open infrastructure that promotes Canada's bilingual research outputs (Coalition Publica, n.d.; SSHRC, 2020a).

As this study explores, APCs are entrenched in a system of prestige, where dominant publishers like the oligopoly set prices based on the journal's reputation. This is a construct embedded in the research assessment system, where researchers seek prestigious journals to secure tenure and promotion, which especially impacts early career researchers. It is vital that a shift in research assessment practices take place to disentangle reward from prestige. The Tri-Agencies have taken steps to support diverse assessment practices, whether as signatories on the Declaration on Research Assessment (DORA, n.d.), NSERC's revised *Guidelines on assessment of contributions to research, training and mentoring* (Government of Canada, 2022), or discouraging peer reviewers from considering the impact factor or h-index when evaluating the merit of an application²². However, more can be done, such as including the assessment of open outputs as an indicator of merit. Furthermore, funders can further align their support with existing initiatives that aim to reform the assessment of research practices, such as the Coalition for Advancing Research Assessment (CoARA), the Higher Education Leadership Initiative for Open Scholarship

²² See p. 18 of NSERC's 2022-2023 Discovery Grants Peer Review Manual <https://www.nserc-crsng.gc.ca/doc/Reviewers-Examineurs/CompleteManual-ManualEvalCompletemanual-eng.pdf>

(HELIOS), Humane Metrics Initiative (HuMetricsHSS) (CoARA, n.d.; HELIOS, n.d.; HuMetricsHSS, n.d.).

Finally, a system to better track and monitor Tri-Agency funded research can not only provide a more comprehensive understanding of existing practices but also provide insights on the unintended consequences of policies and provide ways to reduce systemic barriers that hinder compliance. Research has shown that OA policies can only work when they are monitored (Larivière & Sugimoto, 2018). One way to monitor compliance is by supporting the systematic use of persistent identifiers (PIDs) like ORCID to provide a more interconnected system that can reduce researcher burden and give the funder better insights into the research they fund (ORCID, n.d.). A recent study has shown that researchers manually add identical information into funding and institutional systems, creating an administrative burden for the researcher (Goddard, 2021). PIDs can automate these administrative tasks and reduce the “repetitive aspects of bureaucratic record keeping” researchers encounter in such systems (Goddard, 2021, para. 12). Although some institutions may not have the resources or capacity to support such infrastructure, ideas such as the creation of a “Canadian information-sharing solution” can be explored (Brown et al., 2022, p. 9).

6.3 Concluding remarks

This study’s findings are limited by the biases of WoS, like its under-representation of SSH and non-English publications. However, there are new, more inclusive, open, and non-proprietary databases, like OpenAlex, which yield a more comprehensive understanding of research trends due to its broader coverage (OpenAlex, n.d.). OpenAlex began in a response to the discontinuation of Microsoft Academic Graph, and aimed to be a fully-open replacement with open data, open API, and open-source code (Priem et al., 2022). Such inclusive sources that index a broader

coverage of the world's scientific outputs not only supports more rigorous bibliometric analysis of research patterns, but it also ensures the related decision-making is grounded in a more equitable understanding of global trends. This is critical to the Tri-Agencies, as WoS limits SSH outputs, and research produced in languages other than English.

This study estimates the total APCs paid to oligopoly publishers and demonstrates that moving the burden of payment from reader to author merely moves the paywall, where for-profit publishers grow their OA portfolios, and profits, alongside their well-established traditional model. Despite efforts to lower subscription fees through consortia efforts, university libraries and researchers have been paying more and more to access scholarly literature (Simard et al., 2021). Instead of making scholarly publishing sustainable and accessible for all, the author-pays model seems to preserve the status quo, benefiting large and established commercial publishers, like the oligopoly, and further exacerbating inequities within the system. 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)

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APPENDICES

Appendix A – Tri-Agency OA Policy on Publications

Tri-Agency Open Access Policy on Publications

1. Preamble

The Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC) ("the Agencies") are federal granting agencies that promote and support research, research training and innovation within Canada. As publicly funded organizations, the Agencies have a fundamental interest in promoting the availability of findings that result from the research they fund, including research publications and data, to the widest possible audience, and at the earliest possible opportunity. Societal advancement is made possible through widespread and barrier-free access to cutting-edge research and knowledge, enabling researchers, scholars, clinicians, policymakers, private sector and not-for-profit organizations and the public to use and build on this knowledge.

Information and communications technology, and in particular the advent of the internet, has transformed the way that science and scholarly research is conducted and communicated. Indicative of this changing landscape has been the steady growth in open access publishing and archiving, which facilitates widespread dissemination of research results. Open access enables researchers to make their publications freely available to the domestic and international research community and to the public at large, thereby enhancing the use, application and impact of research results.

Momentum for open access has been growing as numerous funding agencies and institutions worldwide implement open access policies. The Agencies strongly support open access to research results which promotes the principle of knowledge sharing and mobilization - an essential objective of academia. As research and scholarship become increasingly multi-disciplinary and collaborative, both domestically and internationally, the Agencies are working to facilitate research partnerships by harmonizing domestic policies and aligning with the global movement to open access.

The following principles guide the Agencies in their approach to promoting open access to research publications:

- Committing to academic freedom, and the right to publish;
- Recognizing the critical importance of peer review to the scholarly communication ecosystem;
- Maintaining the high standards and quality of research by committing to academic openness and responsible conduct of research;
- Promoting recognized research best practices and standards across disciplines, and embracing and sharing emerging practices and standards;
- Advancing academic research, science and innovation;
- Effective dissemination of research results; and

- Aligning activities and policies between Canadian and international research funding agencies.

2. Policy Objective

The objective of this policy is to improve access to the results of Agency-funded research, and to increase the dissemination and exchange of research results. All researchers, regardless of funding support, are encouraged to adhere to this policy.

3. Policy Statement

3.1 Peer-reviewed Journal Publications

Grant recipients are required to ensure that any peer-reviewed journal publications arising from Agency-supported research are freely accessible within 12 months of publication. Recipients can do this through one of the following routes:

- a. **Online** **Repositories**
Grant recipients can deposit their final, peer-reviewed manuscript into an institutional or disciplinary repository that will make the manuscript freely accessible within 12 months of publication. It is the responsibility of the grant recipient to determine which publishers allow authors to retain copyright and/or allow authors to archive journal publications in accordance with funding agency policies.
- b. **Journals**
Grant recipients can publish in a journal that offers immediate open access or that offers open access on its website within 12 months. Some journals require authors to pay article processing charges (APCs) to make manuscripts freely available upon publication. The cost of publishing in open access journals is an eligible expense under the [Use of Grant Funds](#).

These routes to open access are not mutually exclusive. Researchers are strongly encouraged to deposit a copy of the final, peer-reviewed manuscript into an accessible online repository immediately upon publication, even if the article is freely available on the journal's website.

Grant recipients must acknowledge Agency contributions in all peer-reviewed publications, quoting the funding reference number (e.g. FRN, Application ID).

3.2 Publication-related Research Data

CIHR only

Recipients of CIHR funding are required to adhere with the following responsibilities:

- Deposit bioinformatics, atomic, and molecular coordinate data into the appropriate public database (e.g. gene sequences deposited in GenBank) immediately upon publication of research results. Please refer to the [Annex](#) for examples of research outputs and the corresponding publicly accessible repository or database.

- Retain original data sets for a minimum of five years after the end of the grant (or longer if other policies apply). This applies to all data, whether published or not. The grant recipient's institution and research ethics board may have additional policies and practices regarding the preservation, retention, and protection of research data that must be respected.

4. Implementation Date

CIHR

For research funded in whole or in part by CIHR, this policy applies to all grants awarded January 1, 2008 and onward. While not required, researchers holding grants that were awarded prior to January 1, 2008 are encouraged to adhere to the requirements of this policy.

NSERC and SSHRC

For research funded in whole or in part by NSERC or SSHRC, this policy applies to all grants awarded May 1, 2015 and onward. While not required, researchers holding grants that were awarded prior to May 1, 2015 are encouraged to adhere to the requirements of this policy.

5. Compliance with the Policy

Grant recipients are reminded that by accepting Agency funds they have accepted the terms and conditions of the grant or award as set out in the Agencies' policies and guidelines. In the event of an alleged breach of Agency policy, the Agency may take steps outlined in accordance with the *Tri-Agency Framework: Responsible Conduct of Research* to deal with the allegation. For research funded by the Agencies, the Institution shall enable researchers to comply with the Tri-Agency Open Access Publication Policy, as amended from time to time.

6. Policy Review

The Agencies will review and adapt this policy as appropriate.

7. Additional Information

A) Various resources to assist researchers in complying with this policy can be found in the [Toolbox](#).

B) Further information regarding how to comply with the open access policy can be found in the [Frequently Asked Questions](#).

Date modified: 2016-12-21

Appendix B – List of imprints/subsidiary publishing companies

Imprint_id	Parent Publisher	Imprint/Subsidiary	Year
	Springer Nature		
1	Springer Nature		
2	Springer Nature	Adis International	2011
3	Springer Nature	Apress	NA
4	Springer Nature	T.M.C. Asser Press/Asser Press	2015
5	Springer Nature	BioMed Central	2008
6	Springer Nature	Bohn Stafleu van Loghum	2007
7	Springer Nature	J. B. Metzler	2015
8	Springer Nature	Macmillan Education	2015
9	Springer Nature	Nature Research	2015
10	Springer Nature	Palgrave Macmillan	2015
11	Springer Nature	Scientific American	2009
12	Springer Nature	Springer Science+Business Media	2015
	Elsevier		
13	Elsevier	Academic Press	2001
14	Elsevier	Pergamon Press	1991
15	Elsevier	Baillière Tindall	2001
16	Elsevier	BC Decker	2001
17	Elsevier	Butterworth–Heinemann	2006
18	Elsevier	Cell Press	1999
19	Elsevier	Churchill Livingstone	2001
20	Elsevier	Digital Press	NA
21	Elsevier	Harcourt	2001
22	Elsevier	GW Medical Publishing	NA
23	Elsevier	Hanley & Belfus	2002
24	Elsevier	Masson	2005
25	Elsevier	Medicine Publishing	2005
26	Elsevier	Morgan Kaufmann Publishers	2001
27	Elsevier	Mosby	2001
28	Elsevier	Newnes	1970
29	Elsevier	North-Holland Publishing Company	1971
30	Elsevier	Saunders	2001
31	Elsevier	Syngress	2006
32	Elsevier	Urban & Fischer	2003
33	Elsevier	William Andrew	2009
34	Elsevier	Woodhead Publishing (including Chandos and Horwood)	2013
	Wiley		
35	Wiley	American Geophysical Union	2013

36	Wiley	Current Protocols	1995
37	Wiley	Cochrane Library	NA
38	Wiley	GIT Verlag	2011
39	Wiley	Verlag Helvetica	NA
40	Wiley	Blackwell	2007
41	Wiley	Wiley Health Learning	NA
42	Wiley	Wiley-IEEE Press	NA
43	Wiley	Wiley Job Network	NA
44	Wiley	Wiley Digital Archives	NA
45	Wiley	Wiley Online Library	NA
46	Wiley	Wiley Open Access	NA
47	Wiley	Wiley Science Solutions	NA
48	Wiley	VCH	1996
49	Wiley	Jossey-Bass	1999
50	Wiley	Ernst & Sohn	NA
	Taylor & Francis		
51	Taylor & Francis	Cogent OA	NA
52	Taylor & Francis	Routledge	1998
53	Taylor & Francis	Informa	2004
54	Taylor & Francis	F1000	2020
55	Taylor & Francis	A.A.Balkema	2003
56	Taylor & Francis	Accelerated Developments Inc.	1994
57	Taylor & Francis	Acumen Publishing	2014
58	Taylor & Francis	Adam Hilger	2005
59	Taylor & Francis	AK Peters	2010
60	Taylor & Francis	Allen & Unwin (Textbooks & Professional Lists)	2020
61	Taylor & Francis	The Analytic Press	2006
62	Taylor & Francis	Anderson Publishing	2014
63	Taylor & Francis	Architectural Press	NA
64	Taylor & Francis	Arnold	2012
65	Taylor & Francis	Ashgate	2015
66	Taylor & Francis	Auerbach Publications	NA
67	Taylor & Francis	Baywood Publishing	2016
68	Taylor & Francis	Bellwether Publishing	2013
69	Taylor & Francis	Bibliomotion	2016
70	Taylor & Francis	BIOS Scientific Publishers	2003
71	Taylor & Francis	Bloomsbury Journals	2015
72	Taylor & Francis	Brunner-Mazel	NA
73	Taylor & Francis	Brunner-Routledge	1998
74	Taylor & Francis	Carfax	1998
75	Taylor & Francis	Cavendish	2006

76	Taylor & Francis	Crane, Russak	1984
77	Taylor & Francis	Colwiz	NA
78	Taylor & Francis	CRC Press (acquired in 2003)[10] This imprint is still used.	2003
79	Taylor & Francis	Curzon	2001
80	Taylor & Francis	David Fulton Press	NA
81	Taylor & Francis	Dove Medical Press	2017
82	Taylor & Francis	Donhead Publishing	2013
83	Taylor & Francis	Earthscan	2011
84	Taylor & Francis	Europa Publications	1999
85	Taylor & Francis	Falmer Press	1979
86	Taylor & Francis	Fitzroy Dearborn Publishers	2002
87	Taylor & Francis	Focal Press	2012
88	Taylor & Francis	Frank Cass	2003
89	Taylor & Francis	Garland Science	1996-2018
90	Taylor & Francis	Gordon & Breach	2001
91	Taylor & Francis	Gower	2015
92	Taylor & Francis	Greengage Press	2013
93	Taylor & Francis	Greenleaf Publishing/GSE Research	2017
94	Taylor & Francis	Harwood Academic	2001
95	Taylor & Francis	Haworth Press	2007
96	Taylor & Francis	Heldref Publications	2009
97	Taylor & Francis	Hemisphere Publishing	1988
98	Taylor & Francis	Hodder Education Group	2012
99	Taylor & Francis	Holcomb Hathaway	2016
100	Taylor & Francis	Karnac Publishing	2017
101	Taylor & Francis	Landes Bioscience	2014
102	Taylor & Francis	Lawrence Erlbaum and Associates	2006
103	Taylor & Francis	Left Coast Press Inc.	2016
104	Taylor & Francis	Maney Publishing	2015
105	Taylor & Francis	Manson Publishing	2014
106	Taylor & Francis	Marcel Dekker	2003
107	Taylor & Francis	Martin Dunitz	1999
108	Taylor & Francis	M.E. Sharpe, Inc.	2014
109	Taylor & Francis	Paradigm Publishers	2014
110	Taylor & Francis	Parthenon Publishing	2003
111	Taylor & Francis	Pickering & Chatto Publishers	2015
112	Taylor & Francis	Planners Press	2017
113	Taylor & Francis	Productivity Press	2007
114	Taylor & Francis	Psychology Press	1995
115	Taylor & Francis	Pyrczak Publishing	2016
116	Taylor & Francis	Radcliffe Healthcare	2015

117	Taylor & Francis	RFF Press	2011
118	Taylor & Francis	Scandinavian University Press Journals	2000
119	Taylor & Francis	Speechmark Publishing	2016
120	Taylor & Francis	Spon Press	1998
121	Taylor & Francis	St Jerome Publishing	2013
122	Taylor & Francis	Swets & Zeitlinger Publishers	2003
123	Taylor & Francis	Taylor Graham Journals	2003
124	Taylor & Francis	Transaction Publishers	2016
125	Taylor & Francis	Westview Press	2017
126	Taylor & Francis	Willan Publishing	2010
	Sage		
127	Sage	CQ Press	2008
128	Sage	Corwin	1990
129	Sage	Learning Matters	2011
130	Sage	Adam Matthew Digital	2012
131	Sage	Talis	
132	Sage	Lean Library	