Knowledge synthesis
The past, present, and future of scholarly communication

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Executive summary

Scholarly communication is a key component of scientific activity. Researchers do not keep their discoveries for themselves but disseminate to peers so that the research can contribute to the advancement of knowledge. More than 25 years ago, the advent of digital means of communication changed the ways researchers could disseminate knowledge: digitization provided opportunities for improving the creation, curation, and access to knowledge. Such transformations of scholarly communication are still happening, and radically modifying how research activity is valued, disseminated, and accessed. This knowledge synthesis describes the current changes in the scholarly communication system and how these changes affect knowledge production across disciplines.

The first section provides a brief historical overview of knowledge dissemination, with an emphasis on two innovations have shaped the ways in which it is performed: the creation of the scientific journal and the emergence of the Internet. Scholarly journals and associated scientific societies allowed for broader dissemination of knowledge and were instrumental in the process of nationalization of scientific activities. More recently, the Internet democratized both production and access to scholarly knowledge, while at the same time increasing corporate control over the scholarly publishing system. This section also recalls the historical functions of scholarly journals, and shows how these functions have changed in modern academe: while dissemination used to be the core purpose of journals, it has lost importance in the digital age given the creation of many online alternatives. Conversely, journals' role in certification and research evaluation have become increasingly important, given the current incentives structure of academe and research evaluation practices, thus reinforcing the symbolic role of publications and the associated capital of publishers.

The second section discusses how researchers' knowledge dissemination practices have changed over time. The number of scholarly journals and papers published has risen exponentially since the 17th century—and even more so since the creation of the Web—and, contrary to what was optimistically believed 25 years ago, the digital age did not democratize scholarship but, rather, increased the control of the research system by for-profit publishers. For example, in 2018, three publishers (Reed-Elsevier, Springer-Nature, and Wiley Blackwell) published more than half of the papers in natural and medical sciences indexed by the Web of Science. In addition to chronicling the rising concentration in publishing, this section also presents the strengths and weaknesses of new innovations in scholarly communication, such as megajournals and preprints. Although preprints are not particularly novel, their importance has intensified during the COVID-19 pandemic, as the value of timeliness has increased in the current situation. The section also shows how monographs have decreased in importance in most disciplines and presents new forms of publications, such as data.

The third section focuses on how the language of scholarly communication changed, with an emphasis on the intensification of monolingualism in science. Over the course of the last century, but particularly since the dissolution of the USSR, English has become the main language through which researchers are disseminating knowledge; first in the natural and medical sciences, but also in disciplines where research topics have a strong national component, such as the social sciences and humanities. This is exemplified by the creation of new journals in English (in non-English speaking countries), as well as by the percentage of papers published in English across the globe. The trend towards monolingualism is clearly observed for French-language universities in Canada. For example, while English-language papers accounted for less than 20% of papers at UQAM in the 1970s, this percentage rose to 95% by 2018. Such asymmetry in languages is crucial to understand in the Canadian context, given the bilingual nature of its research councils, scientific societies, and journals. The chapter also discusses how the COVID-19 pandemic challenges the monolingualism of scholarly communication, as it emphasized the importance of knowledge transfer to the national research community and to practitioners.

The fourth section delves into open science practices, presenting the various forms of open access for both journal articles and monographs and the extent to which these forms have been adopted by various research communities. Open access has grown steadily over the last decade and half of manuscripts that have been searched for were freely available online; a percentage which should reach 70% by 2025. The section describes the benefits of open access for individual researchers, such as increased visibility for their work and, subsequently, higher citation rates on average. The section also examines one type of publisher that has emerged over the recent years: so-called predatory publishers, which accept any manuscript submitted for fee-paying authors. The prevalence of these publishers is non-trivial in the Canadian landscape, as dubious publishers prey upon the deception of a Canadian address. Other "open" innovations, such as open data and open peer review, are also increasingly present in the research landscape; however, the advantages and challenges associated with their adoption remain debated by the research community.

The last section describes how various stakeholders—funders, scholarly societies, and institutions—can influence the future of scholarly communication. Funders have established open access mandates, which have had mixed success. In the case of Canadian mandates, the low compliance of researchers compared to those from the U.K. and the U.S. can be explained by the lack of reporting and of consequences for non-compliance, by the absence of an associated infrastructure, as well as by allowing a deposit embargo—funded researchers have up to 12 months to disseminate their papers in open access. Government and funder initiatives—such as Plan S—have driven libraries towards new contractual arrangements, such as transformative agreements, which redirect costs for subscriptions towards article processing charges for authors. Scholarly societies are also regaining control over publishing through "flips", wherein the society exchanges for profit ownership of their journals to non-profit alternatives. Such flips can only be successful if the proper incentives and shared knowledge dissemination infrastructures are in place.

The report concludes with a discussion of how the current pandemic reminds us of the importance of open and efficient infrastructures for disseminating research results, and highlights the ways in which it can serve as a trigger for the development of collectively-owned dissemination infrastructures.

1. Introduction

Scholarly communication is the process by which research is communicated and consumed. This is an essential component of scholarly work: the dissemination of knowledge is necessary for the advancement of scholarship. It is critical that scholars not only perform research, but also communicate its results to readers—most of whom are themselves scholars—and to the broader public. Due to this critical function, scholarly communication also serves as the foundation for the reputation economy for scholars, whereby researchers are evaluated and rewarded through their contributions to the circulation of knowledge.

Digital technology brought massive transformations to the process of scholarly communication. As with the introduction of any new technology, there have been both positive and negative consequences. The digitization of scholarly communication provided opportunities for improving the creation, curation, and access to knowledge. However, many actors in the ecosystem were poorly equipped to take advantage of these digital transformations. The consequence was that several small publishers, journals, and universities presses turned to large commercial publishers to navigate this turn.[1] This led to the contemporary situation in which scholarly publishing is consolidated in the hands of a few for-profit publishers,[2] whose costs are becoming untenable for the research community, and where access remain limited. The current Zeitgeist is prompting another transformation in scholarly communication: one in which the scholarly community regains control over the production and circulation of knowledge.

This knowledge synthesis aims at describing the past, current, and future state of scholarly communication. It will focus on all disciplines—social sciences and humanities, medical sciences, and natural sciences—with an emphasis on how these broad domains differ in their research dissemination practices. Given the increased internationalization of Canadian research across all fields, the review will not only focus on Canada, but situate Canada in a global perspective when the data and literature allows.

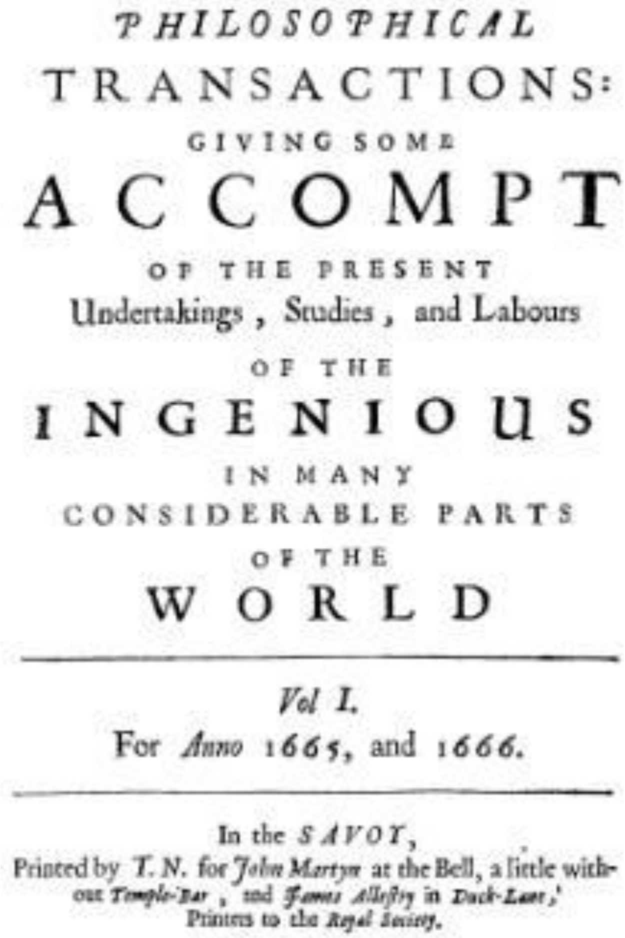
The review will be divided into five main sections. The first section provides a brief historical background on dissemination of knowledge, the effects of the digital age on scholarship, as well as on the traditional roles of journals and books in the research ecosystem. The second section discusses the genre shifts in scholarly communication; focusing on growth of journals and articles, changes in what dissemination media are considered important, and rise in new publication formats. The third section presents historical and contemporary evidence on the place of language in scholarly communication, focusing on English and French. The fourth section delves into open science practices—from open access to open data. The last section discusses the roles (both descriptive and prescriptive) of the various stakeholders in scholarly communication, detailing successful initiatives and innovations by these actors. We close with a call for an open science system, particularly in the wake of the current pandemic.

2. Background

The process through which researchers disseminate scholarly knowledge constantly evolves. While some of these transformations are a consequence of the knowledge that is produced—e.g., the creation of new disciplines and methodologies, or the emergence of contemporary research objects or phenomena—others are the result of external factors, such as social, political, economic, and technological changes. This report embarks on a synthesis of the state-of-the-art in scholarly communication and prognostics for the future, accounting for the changes wrought in the contemporary climate. Before delving into the present and future states, however, it is essential to contextualize these transformations within the history of scholarly communication.

Two major innovations have shaped the ways in which researchers disseminate knowledge: the creation of the scientific journal and the Internet. Dissemination of knowledge in antiquity and the middle ages was relatively slow, with knowledge codified through treaties and epistolary correspondence, with reliance on copyists, whose primary function was the manual recording of ancient texts. These cumbersome and laborious processes meant that the production of texts was slow and limited in terms of number of copies made (and thereby available for circulation). The advent of the printing press accelerated the production of treatises; however, knowledge was still disseminated largely through epistolary correspondence.[3] This can be attributed, in part, to the lower value given to dissemination, which was not as critical to the functioning of the scientific ecosystem as it is today. For instance, most of the scientific studies by Leonardo da Vinci were stored in his series of personal journals, which were not published until after his death.[4] Notions of symbolic capital were not directly tied to output in this era, in contrast to our contemporary indicator-driven environment.

The creation of scientific societies both facilitated scholarly exchange and professionalized science communication. For example, the Royal Society of London for Improving Natural Knowledge—more commonly known as the Royal Society—held weekly meetings to discuss scientific problems and conduct experiments with several observers present. Robert Hooke, the father of the microscope, was considered the "curator of experiments"—akin to a modern scientific editor—and the spectators served the function of peer reviewers. It was not until 1661, however, that the Royal Society first ventured into scholarly publishing with the production of two monographs: *Micrographia* (by Robert Hooke) and *Sylva* (by John Evelyn). The first scholarly journal followed within a few years: on March 1665, under the leadership of Henry Oldenburg, Secretary of the Royal Society, the first issue of the *Philosophical Transactions, Giving some Account of the present Undertakings, Studies, and Labours of the Ingenious in many considerable parts of the World*—or *Philosophical Transactions*—was published.[5]


PHILOSOPHICAL
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INGENIOUS
IN MANY
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OF THE
WORLD

Vol I.
For *Anno* 1665, and 1666.

In the *SAVOY*,
Printed by *T. N.* for *John Martyn* at the Bell, a little without *Temple-Bar*, and *James Allestry* in *Duck-Lane*, Printers to the *Royal Society*.

Figure 1. Cover page of the first issue of the *Philosophical Transactions*

The creation of scholarly journals improved dissemination of research results and, consequently, accelerated the production of new knowledge,[6] which was until then centered on the exchange of correspondence and the publication of treatises which generally took several years to appear. From the 17th century onwards, the number of scholarly journals increased exponentially,[7] and consolidated, for most of the 20th century, their central position in the system of knowledge dissemination,[8] particularly in the natural and medical sciences.[9] These journals have also contributed to the professionalization and specialization of scientific activity, by demarcating the border between popular and scholarly journals and, by extension, the amateur scientist from the professional researcher; the former gradually disappearing during the first half of the 20th century.[10]

The foundation of journals, along with the scientific revolution of the 16th and 17th century, can also be associated with the shift from Latin to vernacular languages.[11] While Latin was the language of treatises since the end of the Middle Ages—replacing earlier Greek and Arabic[12]—its role in disseminating new discoveries decreased as journals were created in national languages: *Philosophical Transactions* (1665) in English, *Journal des Sçavants* (1665) in French, *Giornale de' Letterati* (1668)[13] in Italian, and *De Boekzaal van Europe* in Dutch[14].

One exception was the first German journal, *Acta Eruditorum* (1682), which retained the original Latin. The decision was a function of the audience it wanted to reach, as "[a]n international learned journal of a general nature, which was intended to be read throughout the Republic of Letters, [*Acta Eruditorum*] could not possibly be published in German."[15]

In parallel with the creation of societies and journals, university presses developed in Europe, with Cambridge University Press and Oxford University Press obtaining their letter patents in the 16th century[16]. The first printings were almost entirely religious and then bibliographical[17]. It was only in the 20th century that they more firmly focused on the dissemination of scholarship from their institutions (in parallel with the rise of the research university). This mission was codified by Daniel Coit Gilman, the first president of Johns Hopkins University, upon the founding of the JHU Press in 1878: "It is one of the noblest duties of a university to advance knowledge and to diffuse it not merely among those who can attend the daily lectures but far and wide."[18] Within the first decade, JHU Press had published its first two journals (*American Journal of Mathematics* and *American Chemical Journal*),[19] and its first book, *Sidney Lanier: A Memorial Tribute*, on the University's first poet in residence.[20] By 1900, three other university presses had emerged in the United States: at Chicago (1890), Columbia (1893), and California (1893).[21] University of Toronto was founded in 1901, but it took another 60 years for the emergence of other university presses in Canada: McGill-Queen's (1961), Presses de l'Université de Montréal (1961), and University of British Columbia Press (1971)[22].

Just as today, university presses were filling an important gap in the publishing market: publishing material that would not be economically sustainable by sales alone.[23] Commercial publishing was a competitive industry at the end the 19th century, and there were few market incentives to publish highly specialized work (with high costs and low consumption). University presses thereby addressed this need, in a manner coherent with its scholarly mission: "If the aspiration of the university was to create new knowledge, the university would also have to assume the responsibility for disseminating it."[24]

Scholarly societies continued in parallel to serve the function of developing disciplinary communities and specialized journals[25]. In Canada, the creation of these societies marked the beginning of nationalism in scientific activities vis-à-vis the United States and Britain.[26] It "defined premises upon which a certain Canadian nation could be built, and which gave rise to 'national' policies designed to safeguard that existence".[27] The first journals, however, did not cover all areas of science: Canadian science of the time was mainly of the "inventory" type—cataloging the natural world (resources, plants, rocks, etc.)—and, therefore, the main periodicals created were linked to disciplines of geology and agriculture. As Canadian research activity grew in the first decades of the 20th century, submissions to the *Transactions of the Royal Society of Canada* quickly exceeded the demand. Therefore, the National Research Council founded the *Canadian Journal of Research* in 1929, which became the new home for the publication of basic research in the country.[28]

Later in the century, nationalisation of scientific activities was replaced with a strong push for internationalization of science, to which we can associate important shifts in dissemination languages. While Einstein's and Freud's research were written in German, and those of the Curie and Durkheim were written in French, the end of the Second World War and the phase of internationalization of research that followed transformed research dissemination from multilingual to monolingual, dominated by English.[29] For instance, while at the beginning of the 19th century German represented 75% of the literature in chemistry and English accounted for 10%, German only accounted for 10% of the literature published in the 1960s and English for 50%.[30]

The end of the 20th century was ripe for scientific development, but the biggest transformation for scholarly communication was the growth of digital processes and products. Scholarly articles started a process of dematerialization[31] in the 1970s, when mathematicians began to take advantage of FTP sites for sharing manuscripts and physicists began constructing the infrastructure for what would become the arXiv server. Canada also embarked on initiatives to take advantage of new forms of knowledge sharing. For example, the journal *Surfaces*, founded by Jean-Claude Guédon and colleagues at the Département de littérature compare of the Université de Montréal in 1991, is considered to be one of the first electronic journals in the world.[32] Interestingly, in a recent interview, Guédon mentioned that one of the reasons for creating an electronic journal was that they would not have been able to fund a printed journal. [33] Ubiquitous computing and the advent of the web in the 1990s further reduced constraints on scholarly publishing; increased space, ease of updating, modification, re-use, access, and transmission—at an almost zero marginal cost[34]—radically changed the way researchers produce and disseminate knowledge and the way that knowledge is consumed by other researchers.

While many saw the Web as a way to solve the financial issues of the dissemination of scholarly knowledge—libraries were then, as today, in a "serials crisis"—others believed that it would not provide a sustainable solution for the research community[35]. Interestingly, *Forbes* magazine was part of the group of "optimists": almost 25 years ago, in the 18 December 1995 edition, the magazine published a long piece that stated that Elsevier (which was already the world's largest publisher) would be "the Internet's first victim". As the journalist John R. Hayes wrote, "The web had been created to bring academics together; now it offered them a way of sharing their research online for free. What need would anyone have for fusty, expensive journals?"[36]

As we will see throughout this report, journals and publishers still exist, and have increased their control over scholarly journals—much to the chagrin of academic libraries, which have seen their journal subscription cost increase by 400%.[37] Despite this increased control, digital modes of communication have transformed knowledge-related infrastructures[38] and facilitated internationalization of research.[39] It also led to the emergence of parallel dissemination methods, such as prepublication servers, institutional repositories, and other websites with which researchers can make their articles directly available to everyone, generally with free access.[40] This challenges the traditional function of a journal, which was limited to (a) archiving, (b) certification, (c) dissemination, and (d) registration [41]. In a recent report, these functions were expanded and critiqued (Table 1).[42] For most of the print era, journals had a relative monopoly over these functions. This is no longer the case. For instance, archiving, disseminating and registering can be performed through institutional repositories or disciplinary repositories (such as arXiv, bioRxiv or SocArXiv), and the certification of knowledge claims can be performed through online platforms such as F1000[43] or PubPeer.[44]

Function	Description
Registering	Through publishing, intellectual claims in a given document are associated with a date and authorship which can be used in establishing priority claims.
Curating	Through the process of editorial and other review, documents are selected for inclusion and placed in a collection; this collection functions as a signaling device to associate authors and delineate the theoretical and methodological scope of a domain.
Evaluating	Through the process of peer review, documents are evaluated according to several criteria (e.g., quality and novelty) and authors of these documents receive feedback from their peers; in publishing, the journal certifies that the work has been evaluated; the journal continues to perform evaluative functions by issuing corrections and retractions.
Disseminating	By making the work public, a journal formally disseminates it to a specialist community; through means of open access and other communication tools, the journal makes the work available to broader communities.
Archiving	By supplying the work with adequate metadata and making it available online and to indexes and aggregators, the journal contributes to the permanent scholarly record and provides mechanisms to facilitate discovery.

Table 1. Functions of scholarly journals. From Sugimoto et al. (2018)[45]

The most dominant function of contemporary scholarly journals is a hybrid between the certification and the registration claim, through which scholarly journals become a vector of symbolic capital, and thereby provide a hierarchy of discoveries, authors, institutions, and countries in research. This function is intimately tied to the increasing role of indicators. In 2019, the European Commission released a report entitled "Future of scholarly publishing and scholarly communication",[46] which emphasizes how research evaluation is the key to understanding the current situation and shaping the future. As per the introduction, "the evaluation of research is the keystone, and it has already been identified by scholars around the world, and by various expert groups within the European Commission, as structuring a global research architecture characterised by an unlimited quest for rankings" (p. 3).

The rise in neoliberal policies[47] and university rankings,[48] combined with the ease with which data on research can be collected, has led to the establishment, in several countries,[49] of performance-based funding schemes,[50] even in the social sciences and humanities.[51] One of the most well-know is the UK Research Assessment Exercise / Research Excellence Framework which has been in existence since 1986, and whose adverse effects are well documented.[52] At the heart of these evaluation systems are incentives, which are driving researchers' publication behavior. The role of the journal impact factor—which has become the lens through which the importance of researchers and discoveries of is being assessed[53]—cannot be underemphasized. This indicator, which was created in the 1970s to help libraries choose journal subscriptions based on the citations they received, [54] has become a target for researchers. They need to not only to publish, but to publish in a journal with a certain ranking. For instance, many policies in Chinese universities provide direct financial rewards to researchers based on the impact factor of the journals in which they publish, reaching amounts that can be as high as 165,000USD for a paper in *Science* or *Nature*.[55] Such cash per publication policies have gained traction over the last decade, and have been established in universities in Australia, India, Saudi Arabia, Taiwan, United Kingdom, and the United States, among others.[56] These evaluations of research put constraints on researchers' publication practices; favor specific publishers, research topics, and dissemination languages; and, globally, change of behavior of individual researchers, institutions, research groups.[57] They are also driving marketing and other strategies of publishers.

In reaction to those adverse effects, a few international initiatives have been established, such as the San Francisco Declaration on Research Assessment (DORA)[58], which recommends that scholars and policy makers "eliminate […] the journal impact factor from funding, appointment, and promotion considerations", and "assess research on its own merits rather than on the basis of the journal in which the research is published". Signed by almost 2,000 organisations and more than 15,000 individuals, DORA had a documented effect on researchers' and institutions' publication and evaluation practices.[59] It also paved the way for the Leiden Manifesto[60], which provided 10 principles for guiding quantitative evaluations of research. The effect of the manifesto on evaluation practices is more uncertain, as the interpretation of the principles on which they are based are subjective, and therefore applied in a different manner by researchers and evaluators.[61]

Collective action has also been a driving force behind open access mandates across the world. cOAlitition S, an international consortium of research funders, launched "Plan S" in September of 2018, requiring that all scientific publications funded from these collective funders must be published in compliant open access journals or funders. The initiative has served as a catalyst for journal cancellations and renegotiations. The University of California (UC) system, for example, made headlines in February 2019 when it cancelled its subscription to Elsevier, due to disagreements over open-access terms. The UC comprises nearly 10% of all US research papers and 18% of their published output are in Elsevier journals[62]. The disruption of this cancellation has served as a gateway for other cancellations and renegotiations, largely in the form of "transformative agreements"—whereby libraries shift from a model where they are paying for access to read scholarly publications, to one where they are paying to publish scholarship. All of these activities, however, are part of the ecosystem of scholarly communication. To effect positive change in this environment will require concerted effort among all stakeholders—university libraries and presses, funders, and professional societies.

3. Genre shifts in scholarly communication

Most empirical research in scholarly communication has focused on journals as the seminal work. The emphasis on a single genre has disadvantaged many fields—from book-based humanities research to the fast-paced fields of computer science and engineering, which rely on conference proceedings. However, even these norms are shifting. For example, evidence suggests that the importance of books in the social sciences and humanities has decreased in the digital age.[63] This can be associated to their lower availability: while journal articles are almost all produced in a digital format, and archival journal collections have been digitized, books remain mostly available in the print form and, when digitized, suffer from significant access barriers. Researchers from younger generations are also publishing fewer monographs,[64] which is likely a consequence of pressures to publish and the need to be visible in bibliometric databases for evaluation purposes. This section examines these shifts, using both empirical data on research production, as well as a comprehensive review of the literature. It covers the growth of journals and articles, changes in ownership, and the declining role of monographs. New types of journals (i.e., megajournals) are also explored as well as other platforms for disseminating knowledge, such as repositories. We also examine the shifting concept of a research object: from one that was historically associated with a textual artifact, to one that encompasses data, videos, and other products associated with the generation of new knowledge.

3.1 Growth of scholarly journals

In *Science Since Babylon*, [65] one of the founding works of scientometrics published in 1961, Derek de Solla Price showed that the number of scholarly journals created annually was growing exponentially (i.e., doubling approximately every 15 years) since the middle of the 17th century. While Price saw this as a sign of the growing importance of scientific activity in society, he also stressed that this rate of growth was unsustainable, leading to an environment where each researcher would have their own individual journal. He argued that this exponential increase would end sooner rather than later, giving way to more linear growth. Price's analysis was conducted in the mid-20th century, just as universities' research and teaching activities were beginning to expand. It is therefore important to re-examine the growth rate of science—as measured by the number of new journals—to see whether this rate remains exponential, or whether it has reached a certain level of saturation.

There are relatively few sources that are available to measure the growth of scholarly literature. Most bibliometric databases (e.g., Scopus, Web of Science) have selective coverage,[66] which means that they only index a subset what is published by the research community and therefore cannot be used to measure the overall growth of scholarly literature—especially in the social sciences and humanities and for non-English-language scholarship. To obtain a global portrait of the growth of journal literature, we relied on Ulrich's Periodicals Directory,[67] which indexes more than 300,000 journals and magazines around the world. While it does not contain article-level information, it provides metadata at the journal level (e.g., year the journal was founded, the organization and the country responsible, and the language of publication) and provides a more comprehensive source that traditional bibliographic databases.

Since 1665, the annual number of new journals created followed a relatively exponential growth rate (Figure 2). More specifically, the annual number of new journals created annually went from about 10 per year in the 1850s, to about 100 per year after the First World War, to more than 1000 per year in the 1970s. However, between 1990 and 2005 (see inset), the number of journals created annually remained stable at about 2000. This suggests that Price's intuition was not entirely wrong, and that exponential growth cannot last forever—especially in the print world, where creating journals comes at a much higher cost. While the exploration of the factors behind the stabilization of the growth of journals in the 1980s and 1990s is beyond the scope of this report, we can hypothesize that the print journal was considered to be at the end of its useful life, and that the scientific community—and publishers—considered that there was an appropriate number of journals to meet the scholarly community's dissemination needs.

However, the number of journals created annually started to increase exponentially again around 2004, reaching about 3500 in 2013.[68] This growth is likely a consequence of the digital age and the ease with which it allows for the creation of new journals. A return to exponential growth has given rise to many new opportunities (e.g., open access) and challenges (e.g., predatory publishing). It is worth mentioning that the exponential growth in the number of journals resumed about ten years after the beginning of the digital age, which suggests that it took a certain number of years for digital technologies to be adopted for the creation of new journals. This lag may also be due to the time and resources it took for various publishers and platforms to convert print journals into digital products. As we will demonstrate later in the report, there is also an important number of these new journals that are considered "predatory"—although the exact percentage remains unknown, given the lack of publicly available data on these deceptive publishers.

Figure 2 also shows that the number of journals that ceased publication follows the same trends as the number of new journals, and that slightly more than 20% of journals created since the second half of the 20th century have left the market. We also observe, since the mid 1990s, a decrease in the number of journals that ceased publication; this is likely due to the lag between journal's creation year and the time it takes for them to cease publication—journals created in recent years have not had time yet to halt publication.

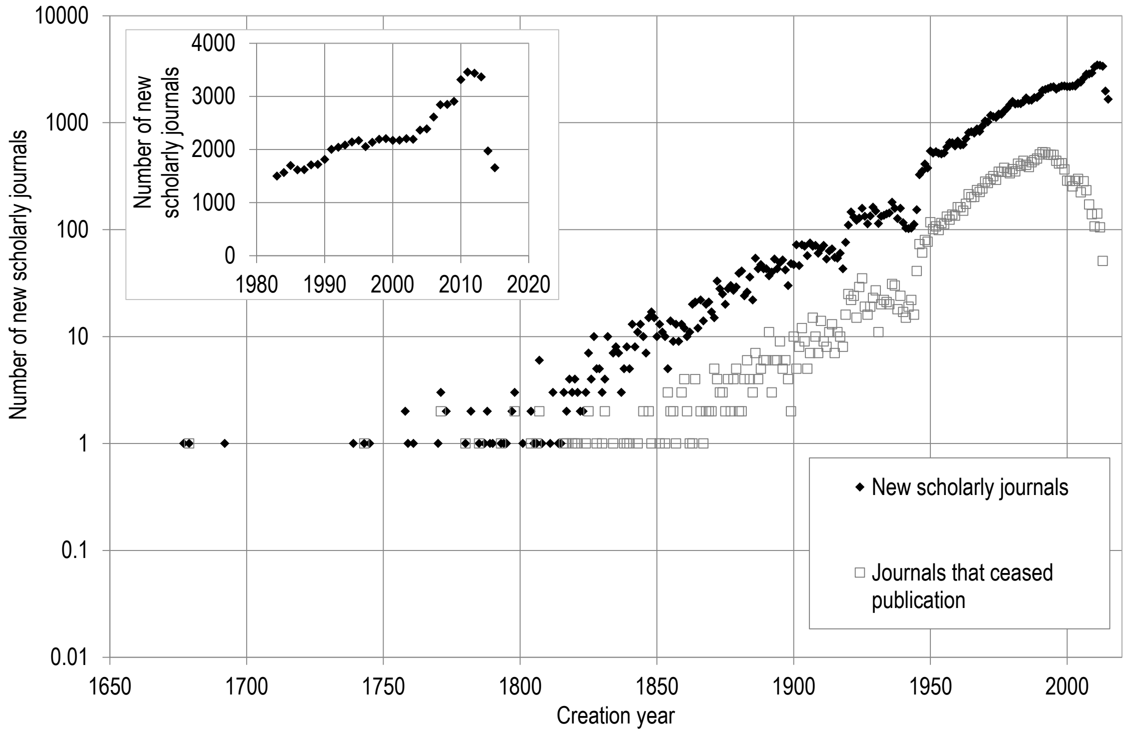

Figure 2. Number of new journals created and that ceased publication, by creation year. Ulrich's Periodicals Directory.

In contrast to journals, the rise in the number of scholarly papers remained almost completely exponential over the last century. Using the dimensions.ai database, which has a comprehensive coverage of contemporary publishing as it builds upon papers that have digital object identifiers (DOIs), the number of papers published annually reached about 5 million in 2018. As Figure 3 shows, the growth of scholarly literature seems to have slowed down at the end of the 1990s, and then increased at a much faster pace afterwards. For instance, the number of scholarly papers essentially doubled in 20 years—from 800k in 1980 to almost 1.7 million in 2000—and then doubled again in the next 11 years, reaching more than 3.4 million in 2011. Explanations for this trend include the increase in the number of researchers worldwide[69]; pressures to publish, which has led to an overall increase in scientific output;[70] and the ease with which electronic journals can be published.

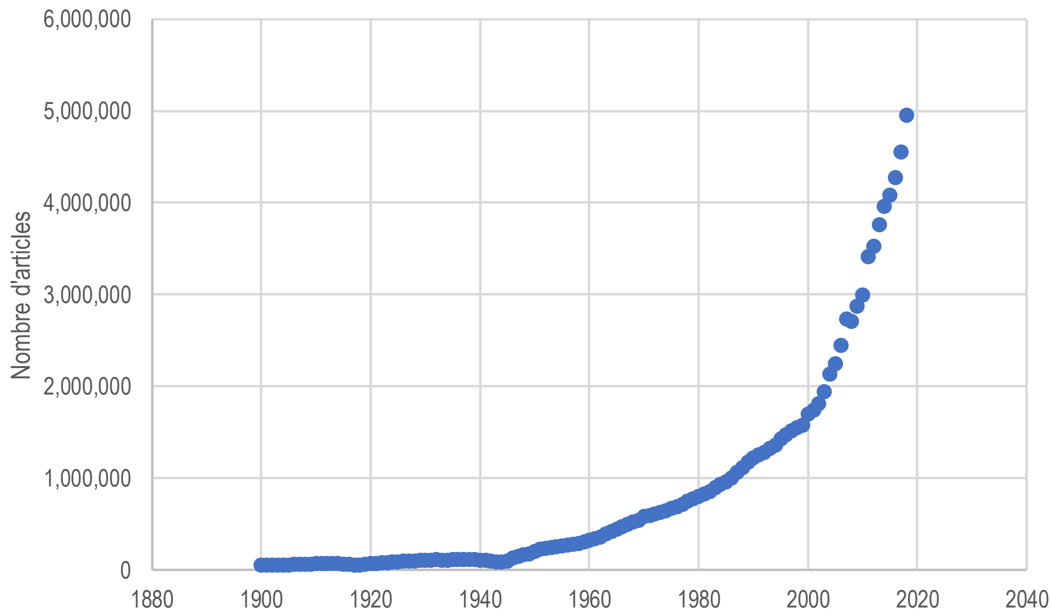

Figure 3. Number of journal articles published, 1900-2018. Dimensions.ai database.

The increase in the number of scholarly papers published varies greatly across research fields (Figure 4). Examining production by four broad domains, we see that about half of scholarly papers are published in the natural sciences (physics, chemistry, biology, mathematics, and engineering). Medical sciences account for about 30% of all papers and has been decreasing over the last few decades. Social sciences account for 18% of research published in recent years. Social sciences has seen the largest growth rate: growing more than five-fold since 2000, compared to three-fold increase in the medical sciences and 3.6-fold increase in natural sciences. Arts and humanities account for a smaller proportion of all research papers (about 1.5%), although it has been increasing at a faster pace than scientific disciplines (four-fold). This may be due to an increasing focus on journal articles, rather than books, in those disciplines (an issue to which we will return later).

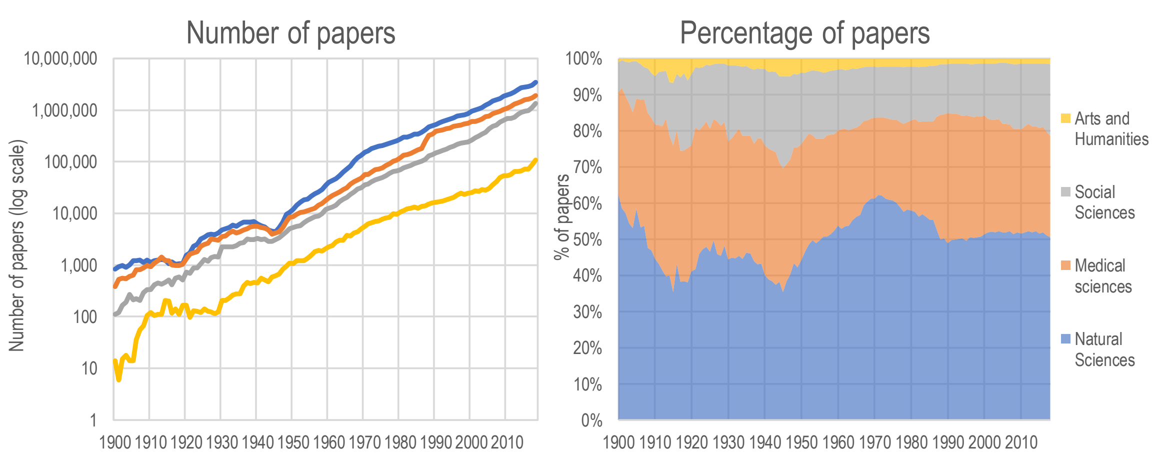

Figure 4. Number (left) and percentage (right) of journal articles published, by discipline, 1900-2018. Dimensions.ai database.

Between 1960 and 2005, the number of newly created journals per organization was relatively stable, and organizations behind the creation of journals were of relatively small size and annually created relatively few journals. From 2005-onwards, however, the average number of journals created per organization increased significantly. The organizations that could take advantage of the digital transformation were those of a certain size, with the expertise, personnel, and infrastructure to make this transition. This is exemplified by the creation of new journals by the two organizations that have created the most journals in the last ten years: commercial publishers Elsevier and Springer (Figure 5). While Springer[71] has created journals at an increasing pace since the 1950s (with a halt between 1995 and 2005), Elsevier's creation of new journals has been stable (and even decreased) between 1980 and 2009, after an increase during the 30 previous years. In both cases, however, the number of journals created increased dramatically around 2005 for Springer and 2010 for Elsevier, and the two firms market more journals today than at any other time in their history.

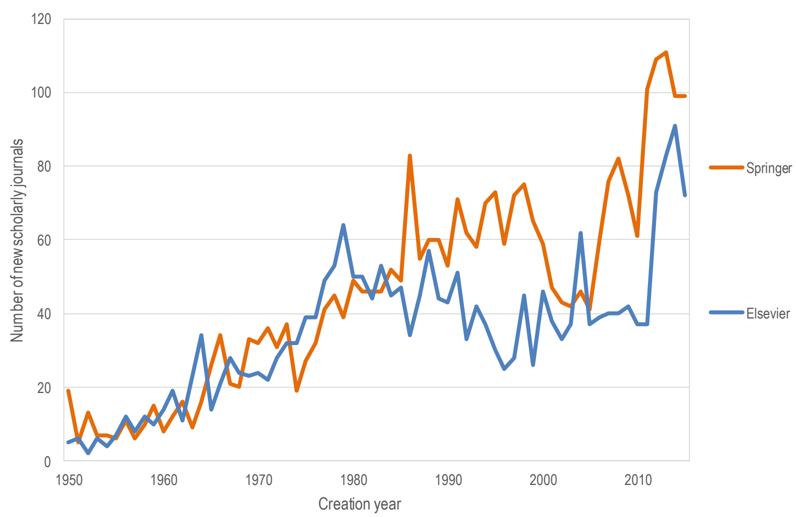

Figure 5. Number of journals created annually by Elsevier and Springer, 1950-2015. Ulrich's Periodicals Directory.

3.2 Corporate control of publishing

As implied above, the control of scholarly journals has increased in the digital age. Previous research demonstrated that, in 2013, five for-profit publishers controlled half of the global scholarly communication market.[72] Using more recent data, we have updated the general trends until 2018 (including additional publishers) to measure whether the situation has changed. Figure 6 shows that (using Web of Science data) there has been an increase in the percentage of papers controlled by the most prolific publishers, and the top seven publishers control a similar percentage of papers (slightly more than 60%) in both natural and medical sciences (NMS) and social sciences and humanities (SSH). The concentration is, however, higher in NMS, with the top three publishers (Reed-Elsevier, Springer-Nature, and Wiley-Blackwell) controlling half of the papers, compared to 37% for the top three in SSH (Reed-Elsevier, Taylor & Francis, and Wiley-Blackwell). Scientific societies and university presses also appear among the top publishers: namely, American Chemical Society, IEEE, Oxford

University Press, and Cambridge University Press. It is worth mentioning that these presses operate in a commercial model that is similar to that of for-profit publishers where profits from publishing serve as an important revenue stream for these learned societies and institutions.

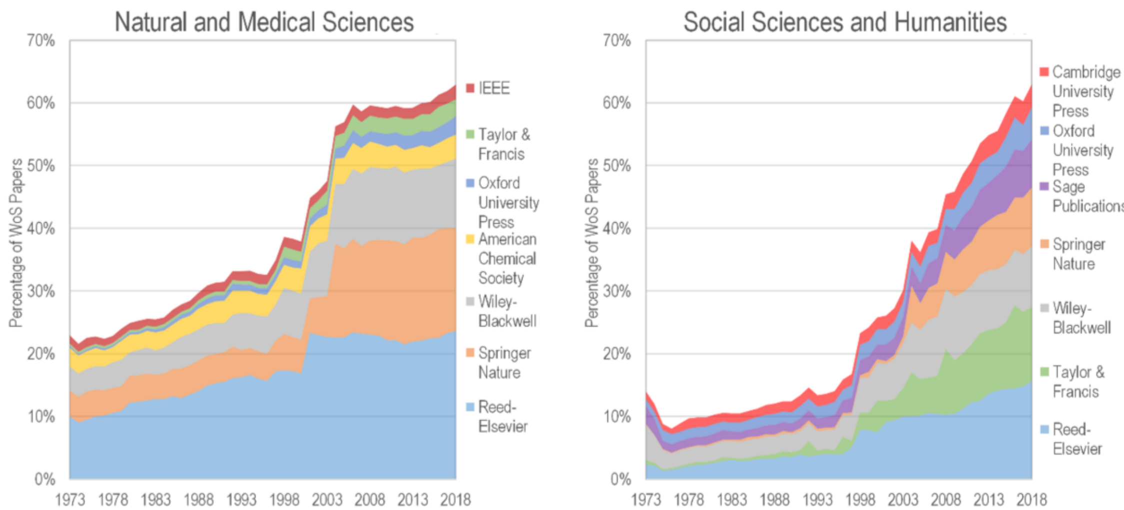

Figure 6. Percentage of papers owned by the most prolific publishers, natural and medical sciences (left panel), and social sciences and humanities (right panel), 1973-2018. Web of Science database, field and subfield classification of the National Science Foundation.

The concentration of scholarly publishing varies drastically across specialties of SSH (Figure 7). For example, 85% of papers in planning & urban studies and geography are owned by five for-profit publishers; Elsevier alone owns 58% of publications in library and information sciences, as well as 39% of economics and 31% of management; Taylor & Francis own a third of education publications, as does Sage in criminology and communications. The humanities are far less concentrated, although two university presses have relative strong control in these areas (i.e., Cambridge University Press and Oxford University Press).

With such a high number of journals in their portfolio, these publishers have developed a new form of journal subscription, known as the big deal. This subscription model provides online access to entire collections of journals rather than individual journals, originally for the price of the print subscriptions of the institution.[73] While such big deals were originally seen as a positive innovation in the libraries' ecosystem—as they provided institutions online access to a much larger number of journals for a lower cost per journal—they have been associated with a sizeable increase (e.g. 400%) in libraries' expenses for journal subscription[74]—an a corresponding rise in publishers' profits[75]—and contain a majority of journals that are seldom used.[76]

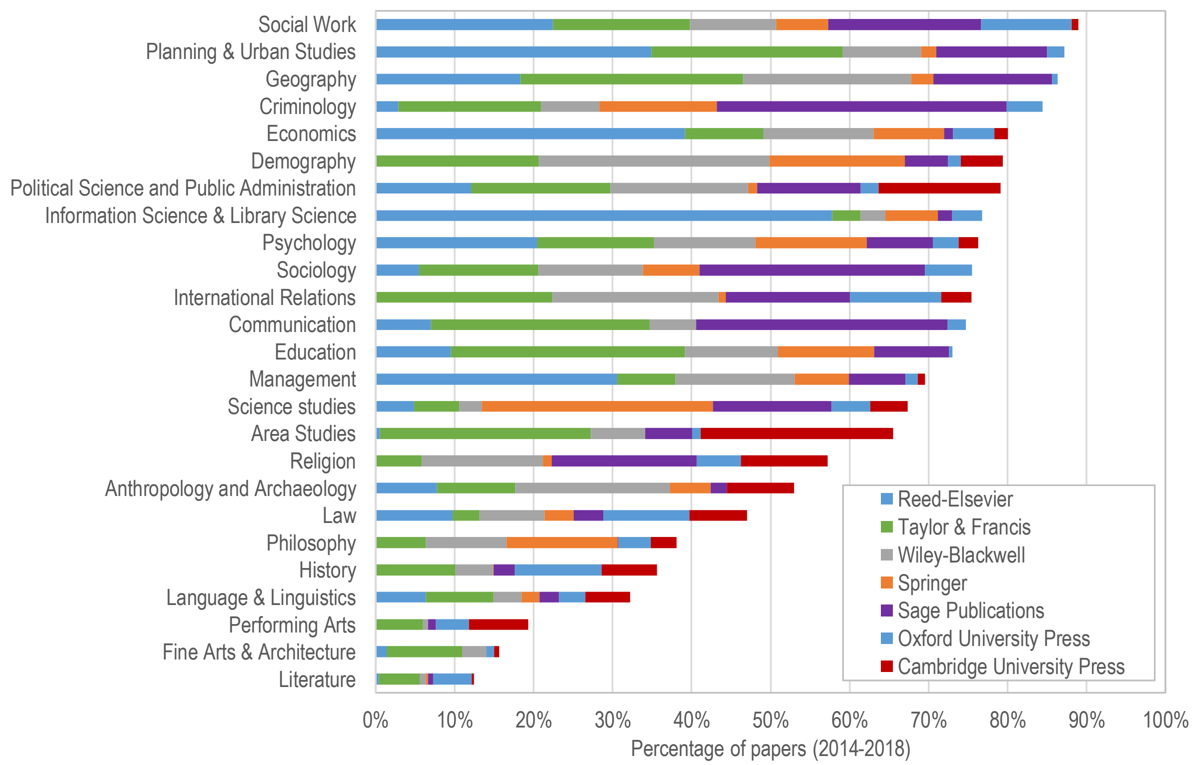

Figure 7. Percentage of papers owned by the most prolific publishers, for disciplines of the social sciences and humanities, 2014-2018. Web of Science database, field and subfield classification of the National Science Foundation.

3.3 Growth of megajournals

The earliest journals and some of the most prominent today (e.g., *Nature* and *Science*) are generalist journals, meant to encompass the entire domain of science. The open access movement, however, gave rise to a new type of multidisciplinary journal: the megajournal. The first of this kind was *PLOS ONE*, launched in 2006 by the Public Library of Science, a non-profit group that was initially funded by the Gordon and Betty Moore Foundation to establish a sustainable model for free-access journals. PLOS became the standard for a megajournal: the journal must be 1) open access, 2) use "soundness only" peer review, 3) have a broad scope, and 4) publish a high quantity of articles.[77]

Of these, soundness only peer review is perhaps the most unique to the megajournal model. This was done partly to respond to the crisis around negative results, but also to reduce bias in peer review[78]. In this system, articles are not evaluated on originality or significance to the discipline, but only on the scientific robustness of the methods. However, in previous studies, those who had experienced megajournals did not notice a discernable difference in peer review; in fact, many stated that they believed megajournals took into account novelty, significance, and relevance.[79] This is perhaps not surprising: it is the same set of reviewers and editors performing labor for megajournals as for traditional journals. It may be that peer review practices will take time to evolve, or that soundness was always the dominant criteria in reviewing (particularly in the natural and medical sciences, where megajournals have been the most prominent).

By 2015, 14 journals were identified that qualified as a megajournals, with *PLOS ONE*—contributing the largest number of papers.[80] However, the absolute number of papers published in *PLOS ONE* decreased after 2013, and *Scientific Reports*—owned by Springer-Nature—has become the largest journal since 2017. A decade ago, it was estimated that megajournals would occupy at least half of the market share of journal articles. That has not come to pass; megajournals only occupy around 3% of the market, despite the relatively high acceptance rates of these journals and their overwhelming size.[81] In fact, as new players have entered the market, submissions to the largest early entrants (e.g., *PLOS ONE*) declined, and *Scientific Reports* now shows signs of stabilization or decrease.

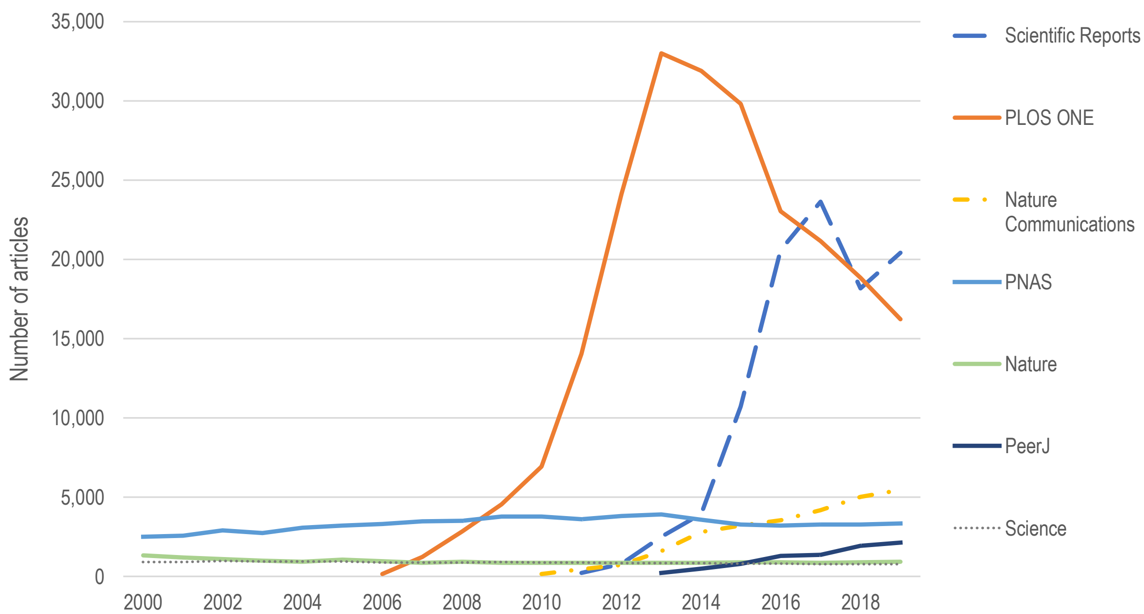

Figure 8. Number of journal articles and review papers published by seven chosen megajournals and prominent generalist journals, 2000-2019.[82]

Megajournals punch above their weight in terms of citations,[83] though some issues have been raised about their self-citation rates and citations directed at editors.[84] These apprehensions also reflect some skepticism in the community about megajournals. Many of the concerns involve the lack of a strong connection with a disciplinary community: the collective credibility of the reviewers and the editorial board is the typical signal of the legitimacy of a journal, yet that is missing in a megajournal.[85] Concerns, however, vary by age and by discipline.[86] Those in communities who had supported early innovations in this space—e.g., life scientists—report enthusiasm for the potential of sharing supplemental materials, supporting data, and otherwise engaging with the community. Those with established preprint practices—e.g., physicists—have questioned not the legitimacy of these venues, but the added value that they provide beyond services like arXiv.[87] Across most previous studies, social scientists, humanists, and mathematicians appear to be the least likely to embrace megajournals.[88] Only a few specialties the social sciences have made sizeable use of megajournals, among which psychology and information science are the most visible.[89]

There has been, over the last decade, an increasing uncoupling of the journal article from the volume in which it was published.[90] The curatorial aspect of the editor-in-chief is no longer viable. With early access views, megajournals, preprints, and online search, researchers are searching for single articles, not collections of articles in a journal. This challenges the conception of a journal, which is no longer the bundling of articles together, but rather the imprimatur of the editorial board, the impact factor, the brand, and the breadth of distribution and marketing. The shift to the article-level was supported by megajournals—PLOS was a strong advocate for article-level-metrics[91]—and, in turn, megajournals represent one of the manifestations of the turn from journal-centric publishing. After PLOS demonstrated its sustainability, many major publishers joined on, using their imprimatur to support the construction of megajournals (e.g., *Nature Communications*[92]). Major publishers also saw this as a way to keep revenue in house: by creating a bucket to grab cascading rejected papers, such as Elsevier's *Heliyon*, *Sage Open*, or *SpringerPlus* (which was discontinued in 2016).[93]

The largest cost of publishing is personnel. Although article processing charges (APCs) present a scalable model (where revenue increases with cost), this also means that journals and publishers often have new and relatively untrained personnel managing the work.[94] If journals get too big, too quickly, there can be a breakdown in quality. Subscription models are unsustainable in this system: the revenue does not increase with the increase in product. Going from "mini to mega requires expensive and technically challenging infrastructure"[95]—therefore, larger publishers are in a better position to adapt to this new system and are taking a larger share of the megajournal market. This suggests that megajournals will not revert from, but rather are likely to reinforce, the concentration of scholarly publishing in the hands of their associated publishers.

3.4 Rise of preprints

As discussed previously, preprints were the earliest form of open access dissemination, mostly in the physical sciences and mathematics. Early preprints servers—such as arXiv, RePEc, or SSRN—which provided early access to unrefereed scholarly papers did not challenge peer-reviewed journals, but accelerated dissemination and increased impact for journal articles.[96] However, the success of arXiv was largely a result of the preprint sharing culture that existed in high energy physics before the construction of the repository. While preprints are virtually absent in arts and humanities, they are increasingly important in social sciences, following the creation of PsyArXiv and SocArXiv in 2016 (with the support of the Center for Open Science). Systems of publishing are not removed from social institutions; they are embedded in and a manifestation of these institutions[97]. This is perhaps why the most successful repositories have been those related to a particular discipline rather than an institution or country.

While adoption of preprints varies drastically across disciplines, medical sciences were relatively late adopters of preprints, largely for concerns about the dissemination of medical information before it had been scrutinized by peer review. For instance, it took more than a two decades after the creation of arXiv to see the adoption of preprints in the medical and life sciences with the creation of bioRxiv (2013) and medRxiv (2019). The COVID-19 pandemic, however, created a massive shock to the preprint system. As the world clamored for urgency in scientific sharing, the use of preprint servers skyrocketed. In the case of bioRxiv, the number of submissions increased from 2,255 papers in June 2019 to 2,303 in December 2019, and then to 3,857 in May 2020—an increase of more than 50% in five months. The numbers have been roughly stable since then.[98] For medRxiv, it is even more drastic: submissions increased from 23 papers in June 2019 to 165 in December 2019, and then 10-fold in four months, to about 2000 in May 2020, and has decreased only slightly since then.

The current increase in use and the critical nature of the COVID-19 research has intensified conversations about the role of review and gatekeeping for preprint servers. Peer review has been the gold standard for scholarship and the increasing concerns about misinformation amplify the need for checks of credibility. However, these concerns are weighed against the urgency of sharing (social concerns) and the desire to accelerate priority claims (individual concerns). To address this issue, the primary biomedical repositories have increased scrutiny and rejection of preprints.[99] It is likely that newer models for dissemination and legitimacy will need to balance these shared concerns of scientific robustness, social good, and personal reputation.

As non-peer-reviewed documents, it has been debated whether preprints should be cited.[100] While the consensus seems to be that they should—as this is what is observed empirically[101]—journals do not have clear policies on that[102]. Another issue associated with the rise of preprints is the lack of indexing of these sources in commercial databases (e.g., WoS and Scopus).[103] As preprints rise in popularity, search engines that include these (e.g., Google Scholar, Dimensions, Microsoft Academic[104]), will become more important. However, these sources are plagued with data cleaning issues and do not lack the standardization necessary for proper bibliometric analyses.

As cultural phenomena, scholarly practices also change with generations. For example, whereas older astrophysics would rely on arXiv digests and SPIRES to find the relevant literature, younger scholars are now using Google Scholar to access these papers.[105] Just as there is a decreasing reliance on journals as the point of entry, so too are repositories losing their claim on being the front door to material. The generational shift is moving from a collection-based approach to an article-based approach for information gathering. Exogenous shocks, such as the pandemic, are also calling into question the lack of transparency and speed in the scientific system. The pandemic is likely to serve as a catalyst for systems that provide early access and transparency in the level of review and credibility for preprints.

3.5 Decline of monographs

The death of the monograph has been a resounding cry for the last few decades.[106] Overall, monograph sales have decreased by orders of magnitude,[107] although it is difficult to obtain precise publication and sales number across publishers[108] and time.[109] Some of the decline in monograph sales has been attributed to libraries, a major purchaser of scholarly material, who have experienced a decline in their budgets[110] in parallel with increasing costs for serials.[111] A few localized studies have demonstrated that there is a decline in the share of monograph *production* compared to other genres.[112] The rare exceptions are in those countries where monographs are explicitly incentivized in evaluation systems.[113] Studies also suggest that there is a preference for using journal articles over monographs for teaching, even in the arts and humanities.[114] The data, however, is highly limited in each of these studies, due to the lack of comprehensive databases on syllabi and monograph production.

Although we cannot comprehensively calculate production of monographs, we can examine the usage of monographs in journal articles' cited references in the Web of Science. The admitted limitation of this approach is that there may be genre homophily—that is, that journal articles may be more likely to cite other journal articles and that the same may hold true with books.[115] However, by taking a diachronic approach, we can reveal proportional trends that may serve as a reflection of monograph production and value to scholarship. We, therefore, extracted all the cited references (more than 1.2 billion) made by 56 million scholarly papers published between 1973 and 2018 from the Web of Science database. We used a very simple criteria—the presence of a volume number in the cited reference—to distinguish between references made to journal articles and to other materials (books, reports, etc.).[116] Although very simple, this criterion makes it possible to divide between what constitutes references made to journal articles (which have a volume number) and references to other types of documents, among which we will mainly find books, usually without numbers. Although there are exceptions (journals without volume and books in several volumes), this indicator allows us to uncover coarse trends in the use of journal articles (and, conversely, books) within disciplines and over time.

Figure 9 provides the percentage of cited references made to journal articles since the 1970s across all fields of science. One can see an upward trend across all disciplines. In biomedical research and clinical medicine, the proportion stabilized two decades ago: nearly 95% of all references in the fields are to other journal articles. The use of journal articles in chemistry has been increasing over the past two decades, now reaching a saturation point similar to the biomedical sciences. Social sciences and the professional fields have seen the most dramatic culture shifts, moving from a minority of references in journal articles to 72% and 62% (respectively) in 2019. All other fields observed similar increases in the 1990s, with the digital turn and intensification of research evaluation in academe. Even the arts and humanities have witnessed this change: while journal articles accounted for about 15-25% of cited references until the late 1990s (and their relative importance was even decreasing for most of the 1980s and 1990s), they now account for about one-third of all cited references.

Although not shown, the trends for Canadian researchers mirror those observed at the global level.

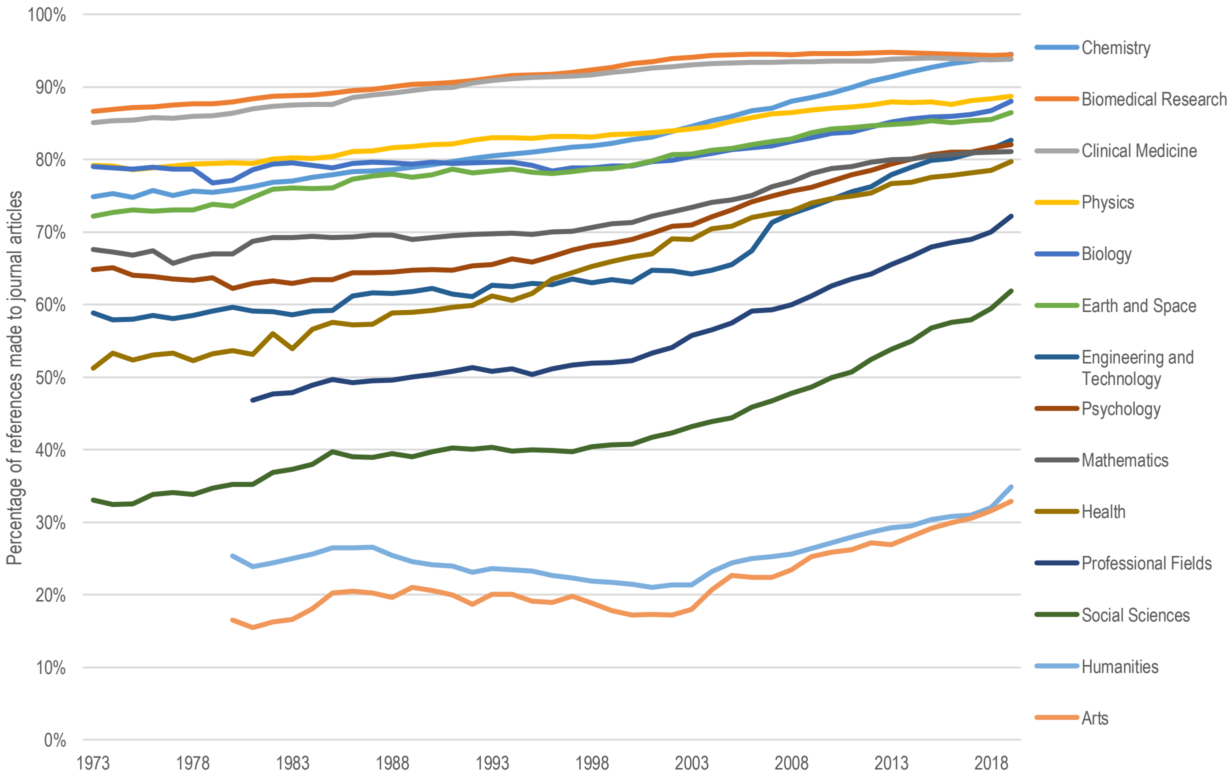

Figure 9. Percentage of references made to journal articles, by discipline, 1973-2019. Web of Science database, field and subfield classification of the National Science Foundation.

These macro-level trends are, however, masking discipline-level specificities. For instance, analyzing the data by decade and using more fine-grained disciplines (Figure 10) shows the growth in the percentage of references made to journal literature is much more important in some disciplines than others: disciplines such as psychology, management, economics, criminology, urban studies, political science, information science, sociology—among others—have drastically increased their use of journal articles. Although decreasing in importance, non-journal material remains the dominant type of document cited in literature, performing and fine arts, area studies, religion, philosophy, international relations and language and linguistics. Two disciplines—history and law—do not exhibit a growth in the use of journal articles. More than half of law references are to journal articles, whereas only about a quarter of history references go to this genre, though these proportions have been decreasing in recent years. This reinforces the importance of monographs in history and, to a lesser extent, in law.

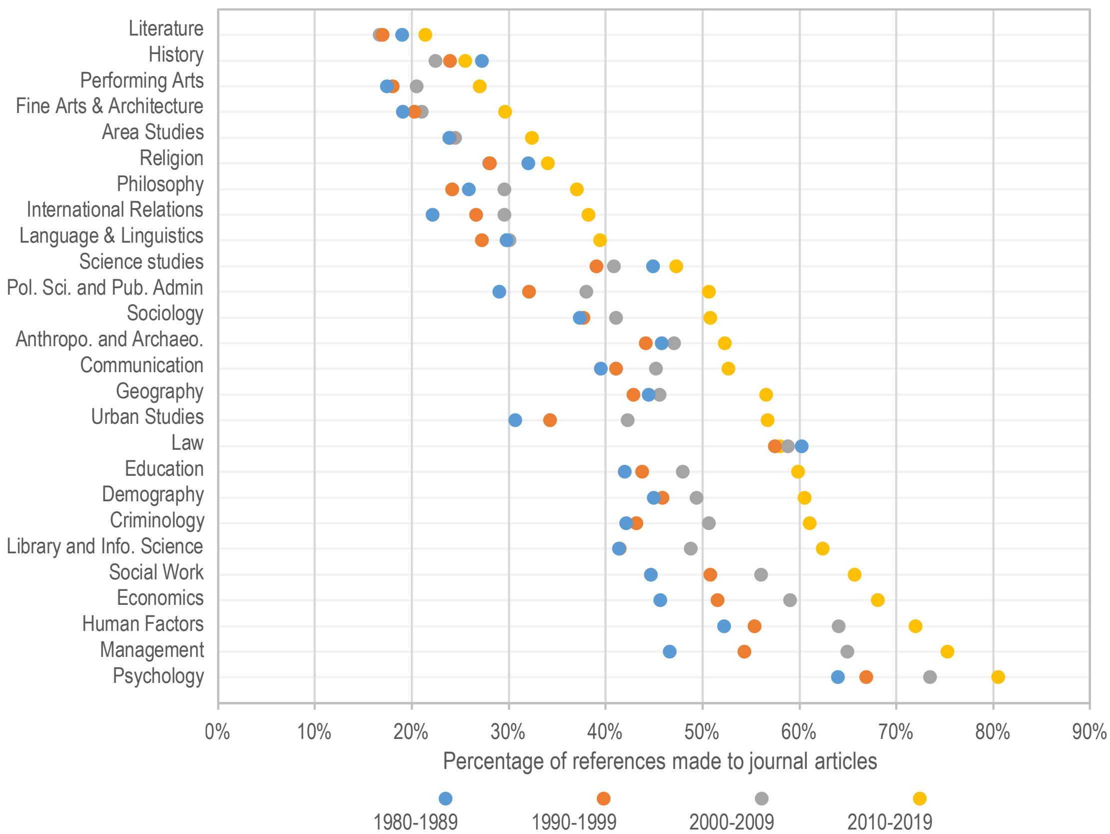

Figure 10. Percentage of references made to journal articles, by discipline of the social sciences and humanities, 1973-2019. Web of Science database, field and subfield classification of the National Science Foundation.

Over the last 40 years, there has been an important increase in the number of cited references per paper in all fields of science (Figure 11). Quite interestingly (and perhaps unsurprisingly), much of the growth in number of references per paper is due to a growth in the journal articles. For professional fields, psychology, social sciences (and for the two broad scientific domains), the mean number of non-journal literature cited per paper remains relatively stable, while they have witnessed dramatic increases in the size of the reference list. This suggests that the growth is entirely attributed to journal articles and decreases the proportional importance of non-journal literature in these fields. This is less the case in arts and humanities, where we observe an absolute growth in the mean number of non-journal material cited in tandem with a rise in referencing of journal material.

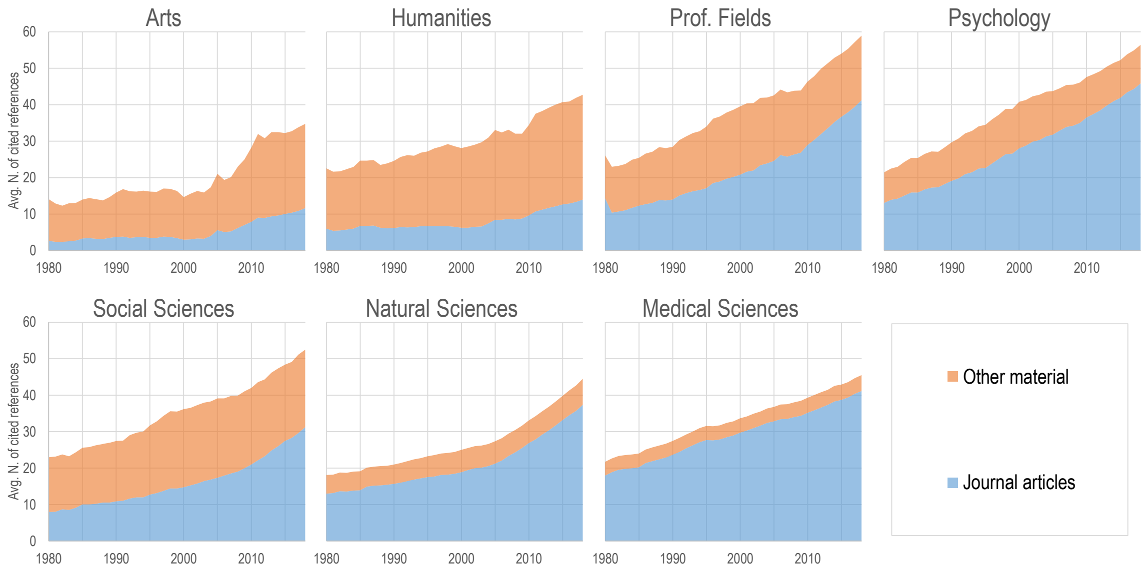

Figure 11. Mean number of references per paper made to journal articles and other material, by discipline, 1973-2019. Web of Science database, field and subfield classification of the National Science Foundation.

The shift from monographs to journal publishing, even in the arts and humanities, has been reinforced in several studies; scholars are, as one article noted "addicted to journal content" as they represent the "lifeblood" of research.[117] One potential explanation for this is the move to electronic content. Journal content swiftly moved online in the electronic era and drastically increased availability and discoverability. Journal articles are also much better indexed in online databases, from the Web of Science to Google Scholar. This impacts discoverability, but also facilitates the construction of indicators. The publish or perish culture has rested on easily constructed indicators from these indexes—the lack of books in this space has devalued them in terms of evaluation assessments. While there is still prestige associated with books and it has disciplinary recognition (particularly in history), the time it takes to write and publish a book does not align with the annual incentive structures in academe. There are also factors internal to the dynamics of disciplines that can play a role. For example, the turn towards the use of mathematical and statistical techniques in economics[118] can be associated with the corresponding rise in the use of journal articles rather than books.

Journal publishers did not immediately take advantage of the affordances of the online article environment; however, the size of a typical journal article met two basic criteria: 1) it could be read online without significant duress; and 2) it could be easily printed in a home or office environment. Books, on the other hand, were more difficult to merely transfer into the electronic realm. There was, of course, the "enduring attachment of many scholars to physical books and preference for reading print".[119] The persistence of the "cultural and symbolic value"[120] of the print book dampened enthusiasm among authors and publishers for innovations in this space. There was also a lack of technology expertise among scholars in this area, which is not the case for the present cohort of arts and humanities scholars.[121]

The final straw is the long form: many people were not willing to read long-form texts online.

Some initiatives are beginning to rethink the book and considering how to take advantage of the affordances for the digital environment for the long form. Some of this has been spurred by advances in digital humanities where scholars have demonstrated the innovations that can be brought to the humanities by constructing products in a digital environment. Innovations in XML and TEI were largely driven by the digital humanities; projects such as Scalar, Manifold, TAPAS, Perseides, and Media Commons rethink how dissemination can happen in the humanities.[122] Print conventions, however, still confer a legitimacy and familiarity that digital products have failed to capture. This was noted well over two decades ago and continues to be the case.[123]

Scholarly monographs have a slightly different relationship to academic institutions than scholarly journals. Whereas professional societies historically dominated the production of journals, university presses were the main drivers in the production of scholarly monographs. Many of them—such as Cambridge University Press and Oxford University Press—have had commercial success and are competitive with (and often emulate) for-profit publishers.[124] Institutions, particularly in North America, developed a strong degree of specialization in this market, with institutions developing unique portfolios in terms of topic and discipline.[125] The niche focus reduced competitive and distributed book submission and sales across institutions. Therefore, the future of the long-form may be highly dependent upon innovations within university presses, and on how they can manage to increase availability while at the same time attracting enough revenues to sustain the costs associated with book publishing.

3.6 Data as publication

Digitization has led to the transformation of some genres and the codification of new types of scholarship. Data sharing as a formalized practice, with credit attribution, entered into the conversation in the 1980s[126]. It is only recently, however, that the notion of treating data as a "first class research object" has been heavily advocated. This status implies that the work is available, peer-reviewed, citable, easily discoverable, and reusable.[127] Earlier data sharing failed to meet these criteria in a variety of ways. Data was typically shared in concert with a publication either on a person website, in a designated repository, or on the publishers' website as supplemental documents. It could also be shared privately between researchers. Several issues plagued the exchange and acknowledgement of these data: e.g., determining importance, credit and attribution; unique identification, access, persistence, specificity, and verifiability; and interoperability and flexibility.[128] These unaddressed issues kept data as a second-class research object in that it did not meet the same standards as journal articles and monographs in terms of conceptualization, review, or presentation.[129]

There are several manifestos, standards, and principles that have been put forth to ensure that data can meet these goals. The joint task group of CODATA (the Committee on Data of the International Council of Scientific Unions) and ICSTI (the International Council for

Scientific and Technical Information) put forth several principles, among which was the "status principle"—that is, that "data citations should be accorded the same importance in the scholarly record as the citation of other objects." An implicit assumption underlying this principle is that the reward mechanism would be the driving force to incentivize data sharing. It has been suggested by several scholars that the emphasis on incorporating credit in alignment with previous genres may have been misplaced.[130] This has borne out in several empirical studies.

In 2012, Thomson Reuters—the owners of the Web of Science—added a Data Citation Index. It was anticipated that this would provide a database and, therefore, indicators for the growing number of data repositories.[131] After the first year, four repositories dominated 75% of the index (Gene Expression Ombinbus, UniPort Knowledgebase, PANGAEA, and the US Census Bureau TIGER/SLineShapefiles). Despite the development of the Data Citation Index and several initiatives to encourage citing, data citations remain relatively uncommon, and least in standard ways that can be captured for indicator construction.[132] The exception are fields such as crystallography and genomics, which have a stronger tradition of sharing.[133]

Part of the omission of data from the cited references is the lack of a unique identifier for data. Therefore, several organizations have lobbied for and created DOI services for research data.[134] Despite the laudable effort of these initiatives and arguments in favor of standardization, DOI and ORCID identifiers for data are still scarce.[135] In fact, there has been a decline in the use of DOIs in the Data Citation Index, with only a handful of repositories responsible for data that has both unique identifiers and citations.[136]

A parallel effort was in the introduction of "data publications" (or "data papers"[137]), which has been called an attempt to "appropriate the prestige of authorship in the peer-reviewed literature to reward researchers who create useful and well-documented datasets."[138] In 2009, the *International Journal of Robotics Research* began soliciting "data papers" as a new genre. Two years later, the *Earth System Science Data* journal was launched as a pure "data journals". In 2014, Nature Publishing Group began *Scientific Data*, an open-access journal of publications of descriptions of scientifically valuable datasets. In the last decade, at least 128 journals have moved to accept data papers; however, only about ten of these are dedicated exclusively to data publications.[139]

The inclusion of data papers in these journals solves the issue of peer review,[140] but still fails to address many of the remaining concerns. For example, among even the "pure" data journals, the metadata requested varies considerably. This may be merely a manifestation of the heterogeneity of data across fields, an issue which is amplified in large, interdisciplinary collaborations, where even sharing across the team is complicated.[141] Without clear expectations for metadata and data presentation, the growth of data publication is likely to remain fractured at best.[142] Furthermore, these data papers remain uncited[143], suggesting either that the current indicators are inappropriate for this genre, or that the genre itself lacks utility for science as published output.

3.7 Expanding research outputs

Data is not the only non-textual item which is emerging as a candidate for publication. Research software as a form of publication is also trying to gain citations to validate it, but these remain uncommon and not well-documented.[144] One innovative use of technological affordances has been the rise of videos for scholarly content. For example, the *Journal of Visualized Experiments* (JoVE), provides scientists the ability to demonstrate their methods and results through video.[145] This reconceptualizes scholarly output as not merely text.

Other textual documents have also sought the credit and attribution of publications. For example, the scholarly blog has had some ebbs and flows in popularity, but has not risen to the state of a scholarly document as some presupposed. For example, there was a large debate on the preprint repository arXiv on whether authors could link back to their blogs. The community felt that this served as an endorsement for material that was not validated by the community[146]. The distinction here between a preprint and a blog is an important one; as is the determination that one constitutes something worthy of scientific discussion and dissemination, whereas the other does not. However, these types of conversations continue, as the processes of scholarship are increasingly being documented and discussed online and the division between what is published and not is increasingly blurred.

Digital tools also allow for not only new modes of publishing, but configurations of ownership and access that are sensitive to cultural dimensions of knowledge production and dissemination. RavenSpace,[147] for example, is a digital publishing initiative funded by the Mellon foundation, created by UBC Press and in partnership with the University of Washington Press which focuses on Indigenous studies. The platform incorporates Indigenous protocols around the sharing of traditional knowledge. These platforms are useful in expanding not only authorship and audiences, but also in acknowledging knowledge production spaces that have been largely invisible in the Western scientific canon.

Funding agencies are also increasingly acknowledging forms of knowledge production and creative expression that are prevalent outside of the natural sciences. For example, the Social Sciences and Humanities Research Council in Canada defines "research-creation" as "development of knowledge and innovation through artistic expression, scholarly investigation, and experimentation."[148] This definition includes forms of creative expression that appear in the visual and performing arts. These expansive definitions are critical as university adopt evaluation guidelines that affect all faculty—from arts to engineering. Narrow definitions of innovation and production are likely to stymy creativity in academic institutions.

4. Language practices in scholarly communication

Digital technologies have accelerated trends towards the internationalization of science in all fields of research, by facilitating communication—and therefore collaboration—between researchers from different countries.[149] Such trends are not limited to the natural and medical sciences, but are also visible in the social sciences,[150] and progressively in the arts and humanities.[151] Increased globalization has also affected the language used by researchers in communicating science. English has served as the *lingua franca* of the sciences for decades; its place in the social sciences and humanities ecosystem, however, is less established. This is of particular importance in the Canadian context, given the bilingual nature of Canadian research councils, scientific societies, and journals. Research shows, however, that English is also increasingly important in these disciplines and in countries where English is not the sole national language.[152] This section discusses these changes in researchers' dissemination languages using two indicators: the languages of journals created and the language of articles; with an emphasis on disciplinary and country-level differences. It also reflects on the current challenges to the increase monolingualism of the scholarly community.

4.1 Creation of new journals by language

Using data from Ulrich's Periodicals Directory,[153] we present the percentage of journals created by main language since the 1950s (Figure 13). The blue curve shows the increase of English—especially since the 1990s—and the decrease of all other languages—except Russian, which has increased since the 1990s. Since the 1960s, English accounts for more than half of all new journals created, and this percentage increased to almost 70% in recent years. French exhibits a slow decline, and accounts for about 3% of new journals published in the last decade. New journals in German also declined since 2000—after increasing post reunification—and a similar trend can be observed for Spanish language journals. Journals in Chinese are perhaps the most striking: Chinese was the second most common language for new journals in the 1980s, but has been declining since then. This is explained by the fact that until very recently (in the wake of the COVID-19 pandemic), the Chinese government and universities established strong incentives for publication in English.[154]

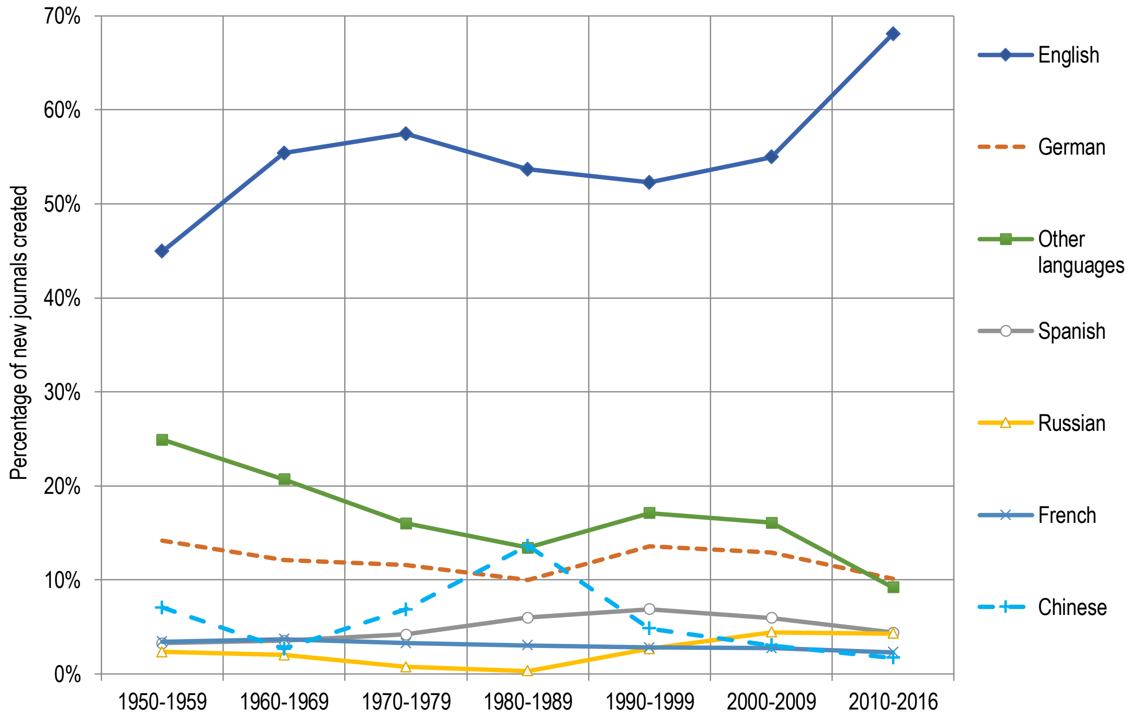

Figure 13. Main language of new journals created, 1950-2016. Ulrich's Periodicals Directory.

In Canada, the linguistic duality has historically led to the creation of journals in both English and French (as well as many bilingual journals). Unfortunately, Ulrich's Periodicals Directory does not have precise information on bilingual journals. Therefore, most bilingual journals—such as the ones from many scientific societies and associations—are categorized as English journals, given that most of their papers are in English.[155] Therefore, our results overestimate the percentage of English-language journals. Figure 14 nonetheless shows that, after a period of relative stability at about 90% of new journals until the late 1980s, the percentage of new journals in English decreased to 80% in the 1990s, mostly because of an increase in the number and percentage of new journals in languages other than English or French. However, from 2000, French declined in favor of English, and almost all the journals created since 2010 were in English. A similar pattern was observed for France and Germany,[156] and our own data also shows the same trends for China—given the pressure to publish in English.

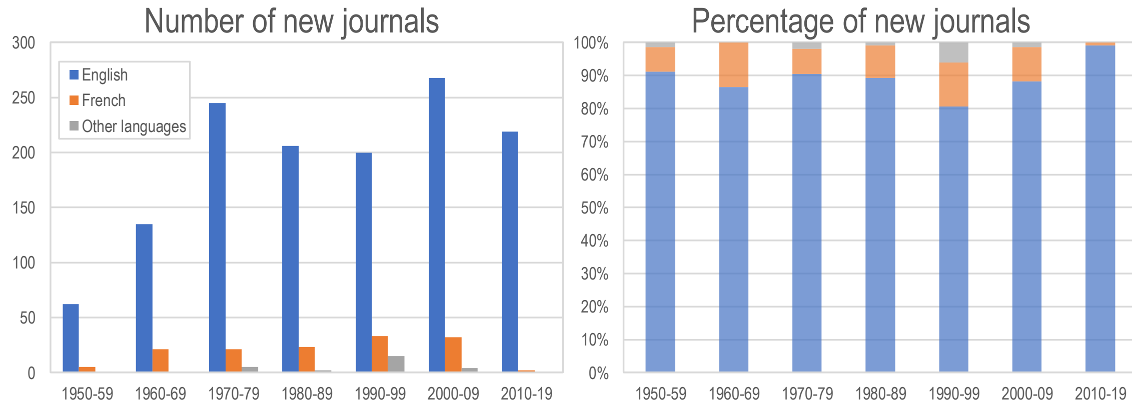

Figure 14. Number (left) and percentage (right) of new journals in Canada, by main language, 1950-2016. Ulrich's Periodicals Directory.

4.2 Language of scholarly papers

As mentioned earlier, the coverage of literature at the paper-level is more challenging to measure, as bibliometric databases have historically relied on the most "international", and therefore, English-language literature, which has underestimated the place of non-English language papers. For instance, according to the Web of Science, English publications were already the main dissemination language for Québec, France, and Germany in the beginning of the 1980s in natural and medical sciences, and now account for almost 99% of the papers.[157] English also became the main dissemination language in the social sciences at the end of that decade. The arts and humanities are moving to dissemination in English, although to a lesser extent than other domains. In the case of Québec, the inclusion of data on journals disseminated through the Érudit platform—which primarily disseminates journals in French—with the Web of Science shows a similar portrait. In 2015, 70% of papers in the social sciences and 40% of papers in arts and humanities were published in English, and the trend was increasing in both domains.[158]

The Dimensions.ai database has broader coverage, but its metadata are not as complete as those of other data sources. It provides an opportunity, however, for us to assess the overall place of English at the world level using a more comprehensive data source which indexes all documents with a Digital Object Identifier (DOI). As Figure 15 shows, the percentage of English-language papers decreased between 1955 and 1995 but has been relatively stable since then. The proportional growth in English-language papers was mostly at the expense of German, French, and Japanese papers. The relative importance of these three languages has been decreasing since 1995, although to a lesser extent than during the previous 40 years. We observe an increase in the percentage of papers publishers in Portuguese—which is likely a consequence of the growth of the SciELO journal platform in the late 1990s (a cooperative electronic publishing database initially funded by the Brazilian funding agency FAPESP and primarily serving the Global South). It is worth mentioning that, despite being relatively complete in terms of scholarly papers for most western publishers, the Dimensions.ai database underestimates the place of Chinese-language papers.

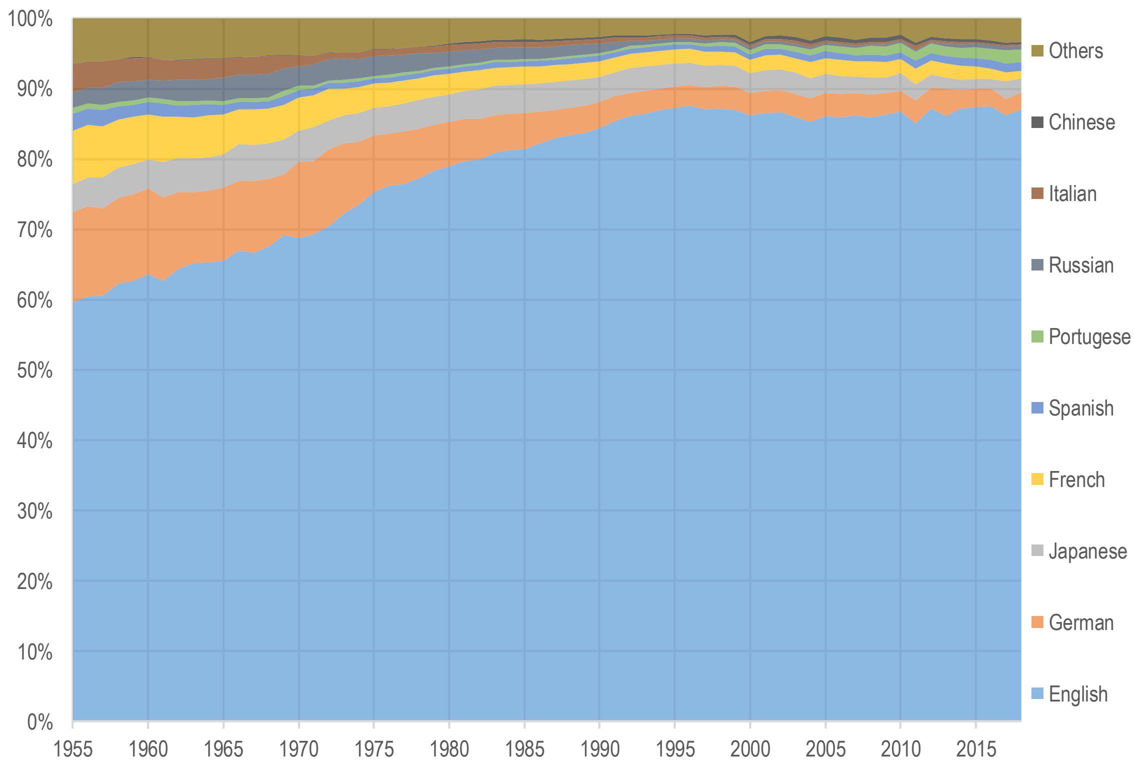

Figure 15. Percentage of papers by language, 1955-2018. Dimensions.ai database.

For the subset of Canadian papers, the trends observed in Dimensions.ai are similar to those observed in the Web of Science, with the vast majority of papers in English in recent years.[159] However, there are strong differences across institutions: Figure 16 shows the percentage of English papers for a sample of representative institutions across Canada. French-language institutions with strong emphasis in the social sciences and humanities (i.e., UQAM, Moncton) have a lower percentage of English-language articles in recent years than similar English-language institutions (e.g., Concordia University). Interestingly, the percentage of English-language articles is lower in bilingual universities in English-speaking provinces (Ottawa, Laurentian) than in English-language universities in Québec (Concordia, McGill). French speaking universities' proportion of English-language papers is lower, but nonetheless accounts for the majority of papers. Taking Université de Montréal and UQAM as examples, we observe that there has been quite a change in publication languages: English-language papers accounted for less than 20% of papers at UQAM and about 75% of papers at Université de Montréal in the 1970s; by 2018, it represented about 95% of papers at both institutions. While UQAM has a much higher percentage of papers published in the social sciences and humanities than Université de Montréal, both institutions have a similar proportion of papers written in English.

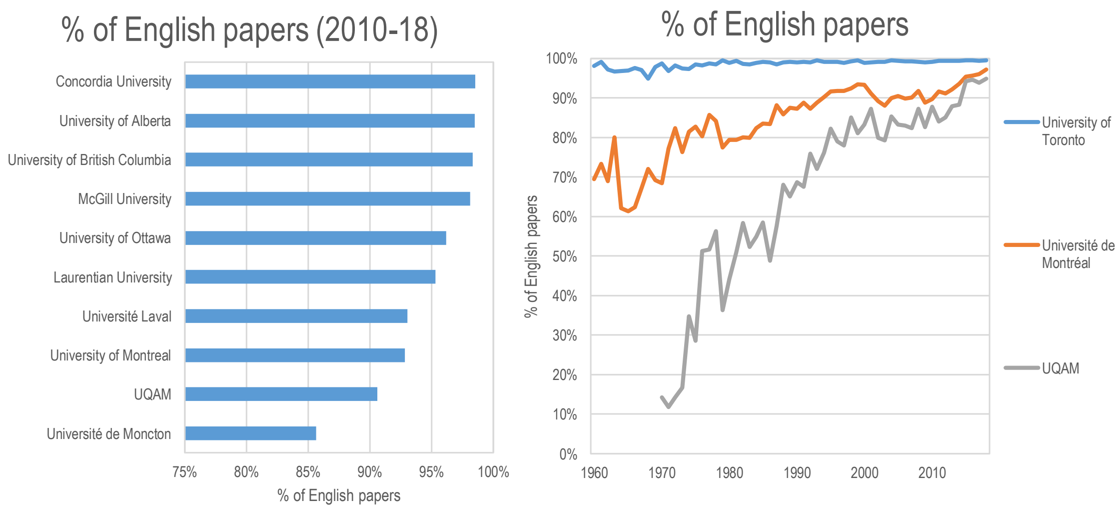

Figure 16. Percentage of English-language papers for selected Canadian universities, 2010-2018 (left) and 1960-2018 (right). Dimensions.ai database.

4.3 Challenges to monolingualism

Several factors influence the relative importance of dissemination languages, among which incentives are probably the most important. Over the last decades, Chinese researchers, for instance, have strongly performed according to the incentives for disseminating research in English. However, these incentives are changing with the current pandemic: after advocating for publication in English,[160] the Chinese government decided to mandate that researchers publish a certain proportion of their papers in Chinese journals to ensure that those can be accessed and understood by the national research community and by those providing health care and crafting policies. The country also eliminated strict paper-based research evaluations, as it realized that prioritizing indicators over the fast dissemination of findings to relevant communities may not in the best interest of society.[161] This is coherent with the recent investment of 29 million USD by the Chinese government in its national journals,[162] which may have major effect on the relative importance of national languages. As China is the country with the most publications at the world level,[163] the place of the Chinese language will likely become much more important in the ecosystem and the non-Chinese community may have to learn Chinese or develop translation services in order to understand some of the research that is coming out of the country—just as researchers who wanted to understand chemistry research 70 years ago had to be able to read German. It would, therefore, be naïve to believe that the current domination of science by the English-language is fixed.

5. Towards an open science ecosystem

Open access of scholarly publications has been the largest transformation wrought by the digital era. The first open access entrant was the use of the Internet to exchange preprints. Then came strong advocacy for free and immediate access to journal articles. From this, several other open practices have emerged: open access to monographs, open data, and open peer review. Each of these new modes of open science brings particularistic opportunities and challenges. This section reviews the shift towards open science, the prevalence of open science across disciplines, and describes how countries are working to provide mechanisms to incentive and enforce open practices. We situate the social sciences and humanities in this conversation, as the emphasis is often placed on the medical and natural sciences. Furthermore, we discuss not only the positive aspects of opening science, but also the negative consequences, such as predatory publishing. We argue throughout for the importance of evidenced-based assessments of innovations in open science and the need for actors to act collectively to responsibly shift ownership and costs associated with publishing.

5.1 Open access

Accessibility is one of the core features of digital scholarship. Physicists and mathematicians embraced early exchange of scholarship using early network technologies, but it was not until the explosion of the Internet that other disciplines began to take advantage of this new environment. The call to disseminate articles online was a blend of technological opportunity and principled ideology. The latter was perhaps best codified in 2002 with the public release of the Budapest Open Access Initiative (BOAI).[164] Organized under the auspices of the Open Society Institute, the BOAI crystalized the definition of open access and served as a catalyst for the dissemination of the concept of open access across the world. The definition in this document became the canonical definition of open access:

> "…free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts […] , crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited."[165]

The BOAI also established a distinction which is still useful today: between self-archiving scholarly papers (green open access) and publishing in open access journals (gold open access). At the time, there were few gold open access journals, but the BOAI anticipated the rise of these, in order to meet the demands of OA.

Self-archiving is the deposit of an authors' manuscript in an institutional or disciplinary repository. Generally, the final accepted version of the manuscript, without the formatting and final copyediting of the journal, is the self-archived version. In some cases, the first submitted version is deposited, which may vary more considerably from the final published version. Globally, about 82% of journals allow authors to disseminate one of the versions of their scholarly papers through green self-archiving.[166] While 75% of publishers allow for the dissemination of post-refereed version of papers, 7% of publishers only allow for the dissemination of pre-refereed versions of papers.

Green open access is free for the author (contrary to many gold open access options), although there is a cost to maintaining repositories. Several models exist for funding repositories. Two key examples are the preprint server arXiv and PubMed Central, which serves as the mandatory repository for research funded by the National Institutes of Health in the US. arXiv functions under a membership model, whereby members pledge to commit a modest amount for a five-year period. This amount is equivalent to the cost of a single paper in a hybrid journal.[167] PubMed Central is funded from the federal government with a budget of about 4.45 million in 2015.[168] It added about 430,000 scholarly papers from authors across the world during the 2015-2016 fiscal year; the majority of which are directly deposited by publishers.[169] Canada also had its own version of PubMed Central—PubMed Central Canada—with the support of CIHR and NRC. However, it closed in 2018, as it had very little adoption by the Canadian research community.[170] Most institutions have also invested in institutional repositories[171] which are crawled by tools such as Google Scholar and Unpaywall,[172] which enhance discoverability. Authors can self-select the repositories on which they make their work freely available, if their license allows for green open access.

Gold open access is generally defined as the free availability of the published version of a scholarly paper through the journal or publisher website. Free availability comes into many shapes, however. Open access can be upon publication—in which case it is coherent with BOAI definition—or after a certain embargo period of a few months to a few years, during which only subscribers have access to the paper. Gold open access can also be free for authors—that is the case for the vast majority of open access journals,[173] many of which (~10,000) rely on free and open systems such as Open Journal Systems[174]—or come at a cost, generally labelled as article processing charges (APCs). Such APCs are highly variable: journals from large for-profit publishers are generally in the few thousands (~ 3000USD), while APCs are often half that for non-profit publishers (e.g., APCs for the megajournal *PLOS ONE* is at 1,695USD). Using all Scopus-indexed journals in 2015, Björk and Solomon reported mean APCs of 1,418USD, with 5% annual increases.[175] The Open APC project, which relies on "fees paid for open access journal articles by universities and research institutions" shows mean APCs of €2,768 for Elsevier, €1,970 for Springer Nature, €2,313 for Wiley Blackwell, and €1,468 for PLOS.[176]

Mandates, manifestos, and government reports have all called for open access.[177] These calls challenged the subscription-based model of most publishers. Therefore, for-profit publishers developed a new type of journal: the hybrid journal. Hybrid journals are subscription journals which provide an option for authors to pay an APC to have their paper openly available in its final form on the journal's website. Hybrid journals generate revenues twice for publishers (subscription and APC), and has been questioned as an ethical publishing practice.[178] While publishers are arguing that they reduce subscription cost proportionally with authors who pay APCs in these hybrid journals,[179] the opacity around journal's cost and the bundle of subscriptions in so-called big deals that have sizeable price increase make these claims difficult to verify.

All forms of open access have been growing over the last decade, and open access is no longer marginal in the scholarly literature. Piwowar and colleagues[180] have shown that, for recent years, about 50% of manuscripts for which researchers searched were freely available online in some format or another, with strong disciplinary differences: while more than half of papers were freely available in biomedical research and mathematics, this percentage was between 10% and 15% in engineering and chemistry. Professional fields (20%), social sciences (25%), and psychology (30%) were also at the lower end of the spectrum. More recent analyses[181] predict that these trends will continue to grow in the next years: e.g., by 2025, 44% of articles will be OA, and that 70% of articles which authors try to find using Unpaywall will be OA.[182]

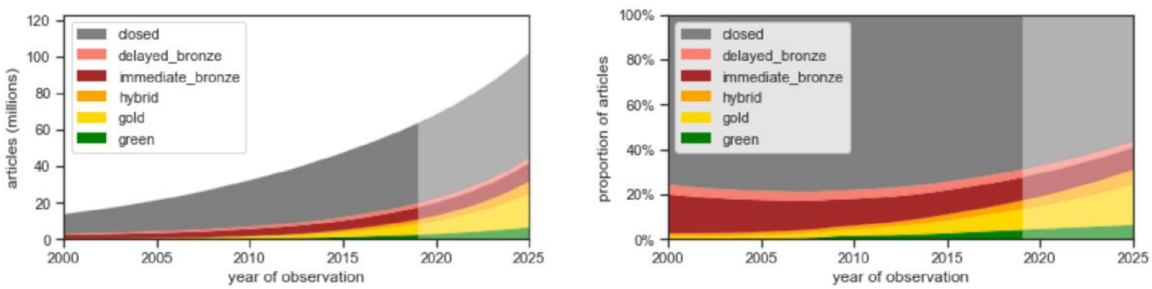

Figure 17. Number (left panel) and percentage (right panel) of articles, by access type, as estimated by Piwowar, Priem and Orr (2019)[183]

The perception of open access publishing has evolved over the last decade. There are many misconceptions about open access: people equate open access with the author-pays model, they assume that open access journals are predatory, that open access lowers the quality of peer review, and that open access is too expensive. Such perceptions are strongly affected by discipline, seniority, and other sociodemographic factors. While academics largely see the value of open access publishing (from both personal and societal dimensions), a minority have published in these venues, with strong disciplinary dimensions.[184] Despite visible policies—like the REF in the UK—many academics are not aware of policies or their adherence to it. For example, an analysis in Spain found that, more than two years after implementation, less than 60% of articles were available in OA.[185] Two-thirds of those that were unavailable were published in journals that allowed for preprints or postprints, demonstrating that the scholarly publishing system was not the determining factor for compliance.

Often used as an argument to convince researchers to disseminate in open access, the relationship between open access and citations has been heavily documented.[186] Most studies observe that open access papers are generally more cited,[187] and that this relationship is observed in all disciplines, from the medical sciences to the social sciences and arts and humanities.[188] At the macro level, (Figure 18), we observe that all types of open access except gold are associated with higher citation rates, and that closed papers receive fewer citations than the average paper. However, the causality implied—papers are more cited *because* they are in open access—has been the subject of debate. Three arguments explaining the effect of OA on citations have been proposed in the literature. The citation advantage could be an effect of 1) self-selection, in which authors choose to disseminate in open access their best work,[189] 2) of faster availability, by which OA papers have started to accumulate citations *before* publication,[190] as they were available to be cited before, or 3) of genuine accessibility, which allows researchers from across the world to access and therefore cited a given piece of research.[191] However, this distinction is likely to disappear in the future, as open access increasingly accounts for the majority of all published work.[192]

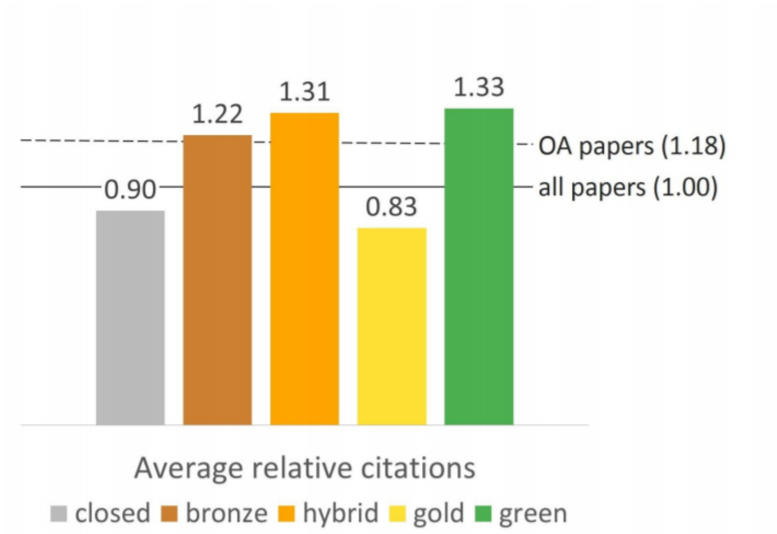

Figure 18. Average of relative citations of open access articles of different types, 2009-2015. From Piwowar et al. (2018)[193]

5.2 Predatory publishers

Commercial legacy publishers are not the only entities that have a financial interest in scholarly publishing. The last decade has seen the rise of a new type of publisher, labeled as predatory (or deceptive) journals and publishers. Those can be defined "entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices".[194] They have been shown to perform practically no peer reviews on the manuscripts they receive,[195] and are ready to accept anyone on their editorial board—even scholars who do not exist.[196] Such deceptive practices are not limited to scholarly journals. They have been documented at the level of fake scientific conferences,[197] and fake journal impact factors.[198] Many predatory publishers cover a large span of disciplines, with the aim of increasing the pool of submissions they may receive. For example, OMICS—a predatory publisher found guilty of deceptive practices and ordered to pay more than 50 million USD to authors[199]—publishes 700 journals, covering nearly all disciplines. The case of OMICS and other predatory journals often leads to a conflation between megajournals and predatory publishing.

While publishers requesting authors to subsidize their own manuscripts with providing little or no quality control have been around for decades in the book culture,[200] such practices at the level of journals remains relatively recent. Three conditions have made possible the rise of these journals and publishers: (1) the ease (technically and financially) with which journals and papers can be disseminated online (reducing the cost of publishing); (2) the acceptance of article processing charges to publish journal articles (making irrelevant the need for an audience for having a readership to generate revenues); (3) the increased pressures from evaluation systems to publish.

Over the last decade, the number of publications from predatory publishers have increased tremendously. Research shows an increase from about 1,800 journals and 53,000 articles in 2010 to 8,000 journals and 420,000 articles in 2014.[201] While the relative importance of this number is difficult to assess, using the number of papers indexed in Dimensions.ai as a baseline suggests that this could represents as much as 10% of scholarly papers published. Predatory publishing is a serious issue, as it jeopardizes the robustness of the scientific record, adds noise to the scholarly literature, weakens the advancement of knowledge, and erodes the trust in scientific institutions.[202] However, these journals are not well-indexed, which means that measuring the extent of the problem or understanding the practices within these journals is problematic. To mitigate the problem, several "blacklists" and "whitelists" have been created—the most well-known being the (now defunct[203]) list created by Jeffrey Beall, librarian at the University of Colorado Denver. While Beall is considered as a controversial figure,[204] his list was considered by many to be a useful resource, particularly for students and new entrants to science. Other organizations have attempted to fill the void created by the removal of Beall's list, with the Cabell's Blacklist being the most well-known. The firm Cabell sells access to the blacklist, which categorizes journals according to more than 60 indicators—thus emphasizing the complexity of defining predatory publishing.[205]

The growth of these journals can be seen by examining the creation of contemporary journals. Using Ulrich's Periodicals Directory—which indexes all new titles—we observe that the growth of new journals has been driven by major corporate entities (Springer and Elsevier, among others), as well as three journals present on Beall's list: Bentham Open, Scientific Research Publishing, and OMICS Publishing Group (Table 2).

Table 2. Top 10 Publishers that created the most journals, 2006-2015. Ulrich's Periodicals Directory.

Publisher	Number of new journals
Springer	870
Elsevier	554
Hindawi Publishing Corporation	549
Peter Lang	484
De Gruyter	366
Inderscience Publishers	293
Brill	248
Bentham Open *	236
Scientific Research Publishing, Inc. *	235
OMICS Publishing Group *	223

* Mentioned on Beall's list

The relative growth of predatory publishers is even greater at the Canadian level. As shown in Table 3, the majority (9 out 14) of Canadian organizations who created four or more journals during the 2006-2015 period are on Beall's list. The strong presence of predatory publishers in the Canadian landscape may be surprising but can (ironically) be explained by the positive reputation of Canadian scientific reputation in the global community. Part of the deception played by predatory journals is to associate the address with a country of high reputation: when these publishers send manuscript solicitations to scholars—promising prompt acceptance, discounts, etc.—, mentioning Canada as an affiliation provides credibility. These trends are also driven by changing ownership of journals: e.g., in 2016, a Canadian publisher of medical journals was purchased by OMICS.[206] With awareness that being on Beall's list would negatively affect their submissions, some of these publishers have sent legal threats to Beall to get their journals removed from the list; this was the case of the Canadian Center for Science and Education in 2013.[207]

Table 3. Canadian publishers that created four journals or more, 2006-2015. Ulrich's Periodicals Directory.

Publisher	Number of new journals
Canadian Center of Science and Education *	40
Sciedu Press *	26
Lifescience Global *	14
Elmer Press Inc. *	12
University of Alberta Libraries	12
Canadian Research & Development Center of Sciences and Cultures *	10
Athabasca University	7
J M I R Publications, Inc.	7
Growing Science *	6
University of Calgary Press	4
Science and Education Centre of North America *	4
Decker Intellectual Properties	4
Better Advances Press *	4
Pulsus Group, Inc. *	4
Other publishers (N=180)	*205*
All publishers	359

* Mentioned on Beall's list

Overall, these numbers suggest that the phenomenon is not marginal, and that several researchers fall (intentionally or unintentionally) into the predatory publishing trap. As these journals are generally not indexed in large-scale databases, analyses on authorship in these journals is limited. Current analyses suggest that authors are more likely to be affiliated with developing countries,[208] but predatory publishing is not limited to these countries. Estimates suggest that about 6% of U.S. papers are published in predatory journals[209] and that 5% of Italian professors have published in such journals.[210] Very little documentation exists on the phenomenon at the Canadian level. One study has shown that about 62% of the faculty of a Canadian business school published in a predatory journal, and that these publications were associated with internal awards.[211] Along these lines, more than 50% of papers published in a sample of medical journals suspected to be predatory had authors from developing countries. This remains lower, however, than their proportion of all papers at the world level. More disconcerting, however, is that 17% acknowledged funding from the National Institutes of Health (NIH),[212] the dominant funding institute for health research in the United States. This suggests either that predatory publishers are successful at their deception, or that scholars' eagerness to publish is outweighing the ethical issues of publishing in these venues.

Little evidence is available on citations rates, but that which does exist suggests that predatory journals are seldom cited (with 60% receiving no citations within five years after publication).[213] The increased inclusivity of citation databases has lead to concerns regarding the potential inclusion of predatory journals in these sources; those citations indexes are often been considered to be a guarantor of quality of journals, and would therefore provide them with an *imprimatur* as well as visibility.[214]

Predatory journals are gold open access journals—this is a negative by-product of the affordances of the online environment. However, while both gold open access and predatory journals offer speed and access for a cost, this is the point at which they diverge. Predatory publishers make decisions "solely based on the gaol of generating revenue rather than promoting scholarship", have "cursory or absent peer review" and engage in "unethical recruitment of authors and editorial board members."[215] Legitimate gold open access journals are largely run by editorial boards from which the academic community, which govern the ethical conduct of peer review. However, there is increasing disquiet within the academic community regarding the exchange of profit for scientific labor and products. As Kingsley and Kennan remarked, "A lot of money has and will continue to change hands in the name of open access, and the big publishers are receiving the lion's share."[216] While it is tempting to demonize predatory publishers and laud other publishers, there is considerable ambiguity in the publishing space. For-profit publishers have been financially benefiting from researchers' dependency on scholarly journals, and predatory publishers do not have a monopoly over unreliable science.[217] Moreover, it has been argued that such arguments against predatory publishers reinforce the place of established publishers,[218] and reduces the possibility for upward mobility in the publication market, especially for publishers from developing countries.[219]

5.3 Open monographs

In 2017, the Higher Education Funding Council for England (HEFCE) signalled an intention to extend the open access mandates of the Research Excellence Framework (REF) to include monographs by 2020. This conversation is still under debate and led to considerable conversation in the academic community, particularly by humanities and some social scientists who saw this mandate as a threat to their traditional modes of production. Advocates were also concerned, questioning the financial viability of this mandate. For example, in an early analysis it was suggested that to publish only 75% of monographs in the REF would cost £19.2M per year.[220] Analyses in the United States have yielded similar results. Studies commissioned by the Andrew W. Mellon Foundation concluded that costs per book would average between 20,000-30,000USD, with the majority of costs going to staffing.[221] These costs far exceed the amount libraries currently spend on monograph purchasing; suggesting that libraries could not simply absorb these costs. Therefore, to implement this mandate, the government, research councils, and institutions would have to collectively create an infrastructure and subventions to support open access.[222]

The Andrew W. Mellon Foundation has invested significantly in examining innovations in long-form publishing. The project on the "monograph of the future" began in 2013. The goal is to move monographs to the electronic environment, taking full advantage of all the affordances of this space: e.g., portable across applications, fully interactive, searchable, amenable to annotation. The project also understands that the work must be financial sustainable and fit into the current academic reward structures, at all levels (institutional and national evaluation systems, and disciplinary reward structures).[223]

There are several strong role models. Australian National University has been publishing open access monographs for more than a decade, with a total of 500 titles.[224] Several other projects have been implemented recently, such as the Luminos initiative of the University of California Press and the Lever Press collaborative initiative between the University of Michigan, Amhurst College, and the Oberlin group of liberal arts colleges. In 2013, the University of Ottawa Press and University of Ottawa Library embarked on a partnership to publish select new monographs as gold OA.[225] The library funded three books per fiscal year (~10k CAD per title); in 2015, they renewed four more books. They are released on the Scholars Portals Books platform and in the University of Ottawa institutional repository (uO Research). The library subvention covers the direct costs of production. The books have had strong download rates and, despite being freely available online to all readers, the books have continued to sell at high rates.

One of the success stories in the book industry has been the move of edited collections online. Such editions have been a dominant form of knowledge production[226] in the humanities and one that easily ports into the digital environment. Digital humanities advocated for these genres because they were able to take archival material, expand accessible, and overlay with critical commentary. The William Blake Archive is a well-known collection, but there are several other collections that serve particular communities (e.g., the collection Nineteenth-Century Disability).[227] These initiatives, however, require investment. At present, few humanities and social scientist have grant funding that would cover publication costs; furthermore, they are socialized to receive at least small royalties from these publications. Culturally, the press denotes prestige on the book. To fully engage in open access monograph publishing will require financial support, community engagement, and revised instruments of symbolic capital.

5.4 Open data

Digital infrastructures have also made possible the sharing of research data—that is the textual and numeric data collected by researchers during the research activity. The rationale for sharing data include: "(1) to reproduce or to verify research, (2) to make results of publicly funded research available to the public, (3) to enable others to ask new questions of extant data, and (4) to advance the state of research and innovation.[228]" These reasons have motivated several research funders to mandate that data be open or shared, with varying levels of infrastructure and stringency. For instance, data on clinical trials funded by the NIH are required to be archived on clinicaltrials.gov[229] whereas the NSF mandates sharing "no more than incremental cost and within a reasonable time" using any mechanism[230]. Journals are also increasingly requiring researchers to deposit the data along with the papers they publish,[231] including high profile journals such as *Science* and *Nature*. Such data sharing and archiving policies are likely to become more important, especially in the current pandemic context.[232]

Despite these motivations and mandates, data sharing remains low and is stymied by the "complexities of data, research practices, innovation, incentives, economics, intellectual property, and public policy."[233] These are tremendous hurdles to overcome. Of course, data varies dramatically by field, with data sharing common in fields such as astronomy, biodiversity[234], crystallography, and genomics.[235] For example, with genomic sequence data, it is often required that these be deposited in an appropriate repository before the corresponding article is sent out to review.[236]

Diachronic studies suggest that there is an increased acceptance of and willingness to engage in data sharing, but also that there are increased concerns about the risk of sharing.[237] Large variations exist by country, age, and field. For example, researchers in the medical sciences and other fields with strong use of human subjects (e.g., psychology and education) are much more concerned about the risks of data sharing than other fields.[238] This creates a tension between the advancement of science and the ethical protection of research subjects. Responsible practices in science have long encouraged the destruction of identifiable data; a Belmont Report[239] for the 21st century is necessary to be able to meet the protections of human subjects while making data available for research. There are also issues of trust and ownership with researchers: researchers may not fully trust secondhand data and may not be willing to part with their own data until they have exhausted its research potential.

There is a wide spectrum of what is considered open data. Data can also be published independently of another article, as a data paper in a mixed journal, or in a pure data journal. Most, but not all data journals are open access. OA journals that accept data papers have, on average, APCs of around €1300 (in keeping with the averages for these disciplines).[240] The limited number of pure data journals (i.e., those only accepting data papers) have much lower APCs: on average around €420.[241] There are very few data journals in the social sciences and humanities and less than a dozen total pure data journals since the first was started nearly a decade ago. This suggests that there is not considerable movement in the field to go towards full distinct data journals and data papers, but rather to place data in association with publication or, occasionally, add a data paper into a journal with other types of research articles.

Data that is associated with another publication is often made available on a personal website, a dedicated repository, or via the publisher's website (when in concert with an affiliated article). This ambiguity and lack of standardization (as discussed earlier) has made allocation of credit for open data more difficult. As noted in earlier sections, even data that is indexed and has a unique identifier is not well-cited. However, papers that make their data available are more cited than those that do not; this is considered the open data citation advantage. This also suggests that linking will be an incredibly important function for open data in the future. There have been several initiates to create standard forms of linking data and associated publications (e.g., the Research Data Alliance (RDA) Publishing Data Services Working group Data-Literature Interlinking Services; Scholix).[242] These services often rely on the availability of both data and publications on pre-existing platforms (e.g., DataCite and CrossRef). There have also been developments in the ability to collect and sore data electronically—this will dramatically change the landscape for the humanities and social sciences as they move towards more digitized and born-digital collections. As the size and scope of collections rise, most infrastructure will need to be dedicated not only to housing data but linking and making data fully available.

5.5 Open peer review

In addition to products, the processes of scholarly communication are also increasingly open. The forms of peer review that operated for the last century are being challenged by new models, largely in response to digital affordances and ideologies of transparency.[243] The assignment of reviewers was historically done exclusively by editors or editorial board members, using their network of contacts. However, as peer review needs have intensified, journals are increasingly relying on automated systems, such as Scholar One (Clarivate Analytics),[244] or Editorial Manager (Elsevier),[245] which suggest reviewers with whom the editors may not have interacted before. While this may be associated with a diversification of the reviewer pool, there are also negative aspects to those systems, such as a potential lack of control over the expertise of reviewers and editors.[246]

Transparency in peer review is another important innovation. Peer review was initially a closed process, done between the editors, authors, and reviewers with many points of asymmetry in knowledge. Single- and double-blind review remain the most common. In single-blind review, the reviewer knows the author's identity, but the reverse is not true. In double-blind review, neither the author nor the reviewer knew the other's identity. However, there is an increasing move towards opening peer review.[247] This can happen in multiple ways. One meaning of open peer review is that the authors and reviewers are known to one another. Another way to open peer review is to make the reviews themselves known. The most transparent is to open the reviews and identify the reviewers publicly.[248] All of these variations serve to increase transparency, but can also have negative consequences on review (e.g., shorter, less robust reviews, and more difficulty in finding reviews). This can also have differential effects for vulnerable populations, such as junior scholars who, as reviewers, may not want to provide critical feedback on a manuscript authored by a senior scholar. Transparency can also mean making information about the process known. At present, there are few ways to gather information across journals about acceptance rates, length of the process, or information about socio-demographic characteristics of the reviewers. Adding transparency to reviews provides more information for potential authors and readers, can encourage equity in gatekeeping, and can serve to add credibility, particularly in the face of increasing predatory publishing.

Online platforms have also led to reviews being performed *after* a given piece of research is being published. Such post-publication peer review can take several forms. The journal *F1000 Research*[249], for example, publishes papers online as they are submitted. However, to be considered as "accepted", papers have to be reviewed by experts invited by the authors,[250] and obtain two "approved" evaluations, or one "approved" evaluation along with "two approved with reservations".[251] Other platforms, such as PubPeer, operate like "journal clubs", that is: researchers provide critical comments on articles published in peer-reviewed journals, which can go from specific questions on a given figure to a general evaluation of a manuscript. Pubpeer has revealed major flaws in some published papers and has been linked to a few cases of retractions of manuscripts.[252] Making work available for public critique by anyone could, in principle, lead to more robust science. However, given the current incentive structure, most of these open peer systems have observed little uptake.[253]

Science is a self-organizing system and peer review sits at the center of that system. Peer review is the essential mechanism through which we evaluate the veracity of claims that can have strong impacts on the social, economic, and physical well-being of citizens. This process, however, has not adequately scaled with the size and complexity of the current scientific environment. Reviewers are overworked[254] and, subsequently, create delays in the system. Researchers, responding to pressures to publish in the highest impact journals are going through a process of cascading submissions, whereby they submit from the highest- to lowest-ranked journals, thereby increasing the total number of manuscripts that needs to be reviewed. Peer review is slowing taking advantage of some digital affordances—e.g., forwarding reviews in this cascading process. Yet, journals and researchers have been reluctant to provide fully transparent peer review. Some of this reluctance is justifiable—editors want to ensure that the process remains robust in an open environment. Yet, other resistance is fear of exposure—that the faults of the peer review system will be laid bare. Only a scientific response is appropriate here: peer review must be systematically evaluated, the process made transparent and open to critique, and recommendations applied and re-evaluated. *eLife*, an open access scientific journal for the biomedical and life sciences, has been a leader in these initiatives—opening peer review for scrutiny and imposing several experiments on the journal.[255] The COVID-19 pandemic has also triggered initiatives to speed up peer review by creating incentives for researchers to review COVID-related preprints and making the content of the reviews open.[256] All institutions that engage in peer review—publishers, institutions, and funders, should add an empirical lens and increasing transparency to their process. Experimentation, evidenced-based policy making, and transparency will be critical for improving peer review in the coming years.

6. Roles for stakeholders

The scholarly communication ecosystem comprises several stakeholders: researchers, universities, funders, scholarly societies, publishers, and the general public. Each of these have different roles and interests in the scholarly communication system. Universities and funders establish incentives and, in turn, shape publication practices. Symbolic capital is created and recapitulated by scholarly societies and publishers. These notions of reputation and capital guide behaviors of researchers. Recognizing the importance of open dissemination of knowledge—both for researchers and the general public—many funders and institutions have adopted mandates in favor of open access.[257] There is, however, variable compliance with these mandates and few infrastructures—both financial and reputational—to support open practices. Revenues from journals are one of the ways through which scholarly societies fund their activities, which increases their dependence on their publishing contracts with for-profit publishers. However, such contracts are considered by many to be unsustainable, as they force university libraries to pay unsustainable subscription costs to for-profit publishers in order to indirectly fund scholarly societies. This section will discuss alternative ways of disseminating the journals of scholarly societies, such as journal flips—with an emphasis on the infrastructure necessary to support such flips—as well as other models, such as transformative agreements. We will also examine open access mandates of funders and institutions with a focus on the factors that can be associated with higher compliance, explore the issue of incentives with the research evaluation culture, as well as the effects of the current COVID-19 pandemic.

6.1 Funders and open access mandates

Funders and institutions play an increasingly prominent role in shaping researchers' publication patterns. In 2008, both the Canadian Institutes of Health Research (CIHR) and the National Institutes of Health (NIH) in the United States implemented open access policies mandating that all papers produced with funding from the NIH be made freely available to the public. Several institutions, such as Harvard University and Massachusetts Institute of Technology, adopted similar mandates. In 2015, the three Canadian federal councils harmonized their mandates, which state that funded papers must be freely accessible within 12 months of publication (embargo), either on a journal or publisher website, or in an online repository. Embargos have been shown to vary by domain; the Finch Report in the United Kingdom recommended a 12-month embargo for STEM and a 24-month embargo for SSH; the combined research councils in the UK (RCUK) OA policy reduced this to 6 and 12 months, respectively.[258] Such embargos were seen by many as a compromise made by funders, as publishers were concerned that reducing the embargo period would threaten subscriptions, despite the lack of evidence to support this.

The rational behind such mandates is simple: most research is made possible through public funds; therefore, the public who funds this research should have access to it. As stated in the Tri-Agency Open Access Policy on Publications:

> "… 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."[259]

According to ROARMAP—which registers funders and universities' open access mandates—there are more than 1000 of these mandates at the world level.[260] Open access mandates, however, differ in their characteristics. For instance, the participation of researchers can be mandatory, encouraged, or optional; the dissemination of papers can be made in any repository or in a specific archive; papers may have to be openly available from publication onwards or there may be an embargo period allowed; and, copyright may be kept by the researcher or their institution rather than given to the publisher. While mandates globally work,[261] their "strength" varies sizeably: some mandates are mere "encouragements", while others are firm contracts with consequences for researchers who do not comply. One mandate with strong compliance is from the Université de Liège in Belgium, which simply states that only scholarship submitted to the institutional repository will be counted in faculty evaluations.[262]

In 2018, a group of major European funders launched a new initiative for open access, named Plan S. As an open access mandate, Plan S is more stringent that most mandates existing at the world level. Plan S requires that, by 2021, all funded research by the supporting funders be made immediately and freely available—i.e., without an embargo—in journals or repositories. The main principles include the following:

- Authors remain copyright (instead of giving it to publishers);
- APCs should be transparent, standardized and capped;
- APCs should be paid by funders or institutions, not individuals;
- Hybrid journals are not supported (but are allowed for a transition period until 2023); and,
- Compliance should be carefully monitored, with sanctions for non-compliance.

Linking scholarly publishing with research evaluation, the participating funders also agreed to base funding decisions on the intrinsic value of then research rather than the reputation (and impact factor) of journals and publishers. Taken globally, these principles de facto made most journals published by commercial publishers—and the majority of journals overall—noncompliant with Plan S. It is therefore unsurprisingly the plan was met with considerable criticism from these publishers,[263] some of which reacted by creating "mirror" journals (i.e., fully gold OA journals which have the same editorial board, scope, and review policy of an existing subscription journal)[264]. In response, cOAlition S revised the plan to explicitly exclude publication in hybrid journals unless the institution had signed a transformative agreement, which would state a specific time at which publications would be fully OA.

Researchers were also divided: while some argued that the plan was a violation of academic freedom, as it does not let researchers publish "in journals that will be important to their careers",[265] others supported the mandate,[266] arguing that it is much more important to "maximizing the reach of our scholarship and its value to the research community and public".[267] While this mandate directly targets researchers funded by these organizations, it will also affect researchers from others countries who collaborate with those funded researchers, and will influence the capacity of journals across the world to attract submissions.

At the level of research institutions, mandates that have been shown to be the most efficient are those where (1) researchers are required deposit papers in the institutional repository immediately upon publication (although papers can remain closed for a certain embargo period), (2) deposit is part of faculty evaluations, and (3) researchers can withdraw from the mandate for a given paper.[268] However, very few analyses exist on the compliance of researchers to open access mandates and on the factors that affect it. The most comprehensive to date covers data until 2017, and focuses on funders in Canada, Europe, the United Kingdom and the United States.[269] Using Web of Science data—which underestimates the production of scholars in the social sciences and humanities, and especially from non-English-speaking parts of the world—the results show, in a manner similar to institutional mandates, that policies are the most efficient where deposit is being made in a designated repository, and where deposit is monitored and included in evaluations. For example, the funder with the highest level of compliance—the National Institutes of Health (NIH) in the United States—makes it mandatory for researchers—or the journals in which they publish—to deposit the funded papers in PubMed Central upon publication (i.e., no embargo on papers' deposit), check compliance of funded papers through a reporting system, and non-compliance is associated with suspension in award processing. The Wellcome Trust in the United Kingdom—which also has very high compliance rates—withholds 10% of the total grant budget until all funded papers comply with the mandate.

The study also highlighted the very low level of compliance of papers funded by Canadian councils: 56% for CIHR, 30% for NSERC, and 23% for SSHRC (Figure 19). While the figure for SSHRC is likely an underestimation—as papers published in journals disseminated through the Érudit platform, which complies with the SSHRC OA mandate, are not well covered in the Web of Science—it suggests that Canadian papers published in international journals are far from compliance with the SSHRC mandate. By comparison, papers funded by the Economic and Social Research Council in the UK were more than two times more likely (69%) to be openly available after 12 months. To better understand the effects of broader inclusion of journals on compliance indicators, we compiled compliance of funded papers that acknowledge SSHRC funding using the dimensions.ai database (Figure 20). Results show that global compliance is slightly higher using dimensions.ai, although the difference is not sizeable (23% vs 26%). However, we observe important differences across provinces, with papers that have a lead author Québec having a higher percentage of compliance (32%) than those from other British Columbia (28%), Ontario, Alberta, and all other provinces, which is likely due to the inclusion of Érudit journals which in open access with a maximum embargo of 12 months.

Results of the international comparison of WoS-indexed papers also demonstrated that disciplinary cultures can be changed by strong open access mandates. For instance, in the field of chemistry—in which publishing is heavily dominated by the American Chemical Society[270]—global compliance remains relatively low at 35% of papers (Figure 19). However, when it is funded by the NIH (with the associated mandate), 81% of papers are available in open access, a percentage that is much higher than the US National Science Foundation (24%) or NSERC (10%). While discipline specificities may be cited as reasons not to comply, these results suggest that mandates with proper characteristics can shape researchers' behavior and override disciplinary concerns. On the whole, these studies show that when compliance is left to the researchers—without a strong incentive structure—it will remain low. This also reinforces the fact that, whether it is for open science or another initiative, funders have tremendous power in shaping scholarly publishing.

Funder	Biomedical Research	Clinical Medicine	Health	Mathematics	Earth and Space	Psychology	Physics	Biology	Professional Fields	Social Sciences	Chemistry	Engineering and	All Disciplines
Wellcome trust	92%	84%	87%	96%	71%	80%	73%	88%	93%	74%	73%	79%	87%
NIH	93%	86%	79%	87%	73%	75%	84%	76%	74%	59%	81%	71%	87%
MRC	88%	75%	79%	87%	62%	62%	47%	83%	77%	73%	59%	50%	79%
Gates	89%	81%	83%	95%	50%	47%	51%	57%	28%	44%	52%	46%	79%
BBSRC	83%	71%	77%	90%	57%	44%	58%	68%	92%	52%	49%	52%	74%
ESRC	92%	76%	72%	70%	66%	60%	69%	60%	59%	63%	60%	56%	69%
ERC	80%	64%	59%	75%	82%	50%	75%	66%	46%	46%	36%	46%	67%
CIHR	71%	51%	52%	73%	43%	22%	36%	57%	47%	26%	25%	22%	56%
EPSRC	76%	64%	70%	78%	59%	54%	60%	68%	58%	62%	39%	49%	55%
NSF	76%	70%	52%	69%	54%	34%	48%	46%	35%	26%	24%	23%	47%
NSERC	57%	38%	42%	55%	31%	18%	40%	28%	14%	8%	10%	12%	30%
SSHRC	78%	35%	25%	40%	33%	17%	27%	36%	14%	16%	0%	17%	23%
All funded papers	85%	79%	73%	67%	57%	56%	56%	51%	42%	39%	35%	29%	66%

Figure 19. Proportion of papers available in open access, by funder and discipline, 2009-2017. Data from Larivière and Sugimoto (2018)[271]

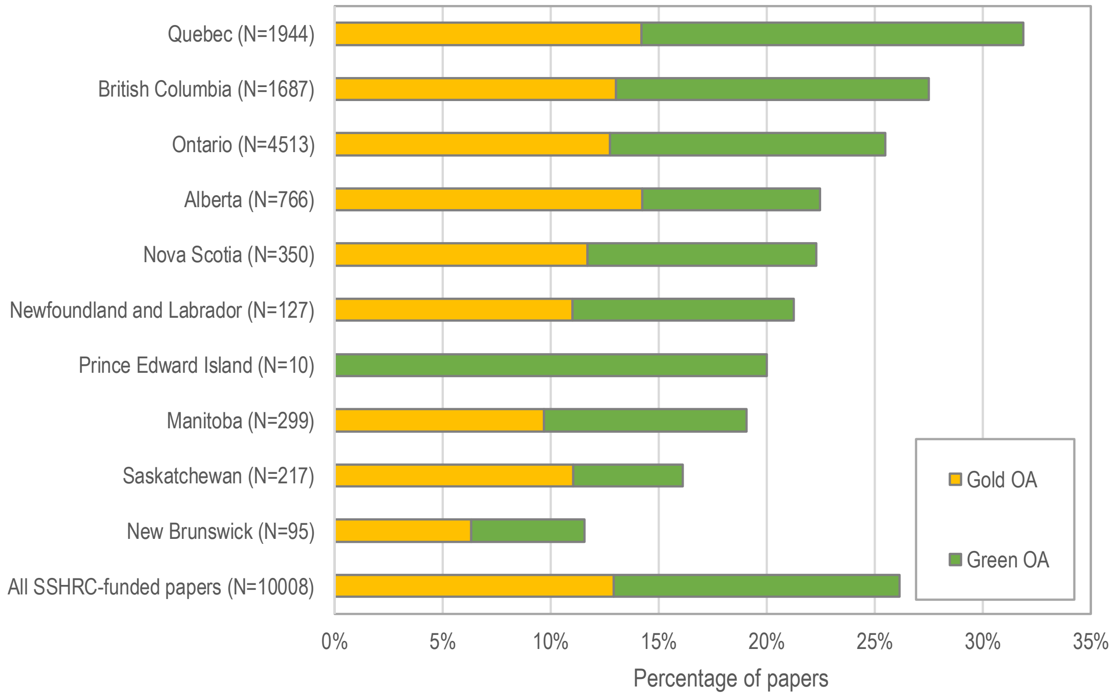

Figure 20. Percentage of SSHRC-funded papers available in open access in 2019, by province and open access type, 2008-2018. Dimensions.ai database.

6.2 Scholarly societies

Scholarly journals are an invention of scholarly societies. However, as we have documented throughout the report, the dissemination of journals is now massively performed by commercial publishers, who provide royalties to societies based on subscriptions and APCs. This system is not sustainable over the long run: in order to indirectly fund scientific societies, universities must collectively pay billions to corporations for their publishing services. In the last few years, some journals shifted back from corporate publishers to non-profit alternatives in a process called a "journal flip". A journal flip implies the collective resignation of the entire editorial team (editor and board) of a journal—or a sizeable proportion of it—to create a new journal with the same editorial team and aim and scope, but under a new name, and generally with new ownership. Two examples of such flips have occurred in the social sciences and humanities recently: the flip from *Lingua* to *Glossa*, made in 2016[272] and from *Journal of Informetrics* (JOI) to *Quantitative Science Studies* (QSS)[273] in 2019. Both journals were published by Elsevier; the editorial team of *Lingua* founded *Glossa* with Ubiquity Press (a British academic-based publisher), and the editorial team of JOI created QSS under the ownership of the primary professional society in the field (International Society for Scientometrics and Informetrics (ISSI)). In the case of QSS, the society chose to work with MIT Press as a publisher.[274]

The two authors of this report were heavily involved in the flip of *Journal of Informetrics*, as associate editor of JOI and board member of ISSI (Larivière) and as board member of JOI and president of ISSI (Sugimoto). JOI had been created by Elsevier in 2006 and had quickly become one of the top journals in the field of information science. However, over the years preceding the flip, members of the editorial team were become increasingly uneasy regarding the high subscription cost of the journal, the amount of article processing charges for open access papers (2,000USD per paper), the lack of control in the operation of the journal and, finally, the refusal of Elsevier to open its cited references to text and data mining—a crucial point for the field of informetrics, which makes heavy use of that metadata. That last piece was, for many members of the board, a deal breaker. As the opening editorial of the new journal stated, by "… by refusing to open its citation data, Elsevier has chosen to fully protect the interests of its shareholders while disregarding the interests of other stakeholders, in particular the scholarly community."[275] The new journal *QSS* was founded in January 2019, and published its first issue in February 2020, containing 23 articles.[276]

Such journal flips are examples of the re-appropriation, by the research community, of their journals, which have become, since the digital age, increasingly owned by for profit publishers. They therefore need the support of their communities, but also financial resources. To support the JOI flip, and in collaboration with the Fair Open Access Alliance (FOAA),[277] the German National Library of Science and Technology (Technische Informationsbibliothek—TIB) provided a grant to cover the article processing charges (between 600-800USD) of the journal for the first three years, meaning that the journal will both be free for authors and readers during the critical initial years. However, sustainability remains a chief concern: the grant covers three years, which means that after this period, APCs will have to be paid by authors and their institutions. The challenges are not just financial; there are also issues across geographic lines. For example, the journal is not yet indexed in a major bibliometric database and does not have a journal impact factor. This places it at odds with the evaluation practices in China,[278] and many European countries.[279] As a result, the members from these countries are not fully engaged with the flip. This reinforces the need for holistic approaches that incorporate both the technical and the social as we innovate within the scholarly communication system.

Scholarly journals have historically been a way for scholarly societies to fund their scientific activities. Therefore, many of them—in Canada and elsewhere—are relying heavily on their current publishing contracts with for-profit publishers. While agreements with commercial publishers can be considered as a win-win situation—professional societies gain monetary incentive and publishers ensured dissemination of journals—the collective cost for this may be too high. The creation of public infrastructures by funders and universities would provide societies with alternative modes for disseminating the journals of scholarly societies—which represent a large proportion Canadian SSH journals—keeping in mind the funding necessary for such organization to fulfill their duties, and how they can use their scientific capital to improve the scholarly dissemination system. This, in turn, would create the conditions under which societies would be willing to perform journal flips, such as the one performed from *Journal of Informetrics* (Elsevier) to *Quantitative Science Studies* (MIT Press). In a context where the current pandemic will likely affect these societies' revenues, it may be the appropriate time to collectively rethink how these organizations are supported, as the current model—in which universities pay more than they should in subscriptions to for-profit publishers, of which societies obtain a tiny percentage—is unsustainable. Direct support from universities and funders is likely to be collectively less expensive than funding societies through subscription to their journals in big deals.

In a context where several funders throughout the world are moving to more stringent open access mandates, these flips are a way for societies to ensure that their journals can thrive in this new environment. And while commercial publishers argue that they support open access,[280] their actions do not necessarily follow. For instance, a 2019 European Commission report[281]—which was based on the joint work of both "independent experts" and "experts representing organisations" (funders and publishers)—recommended that publishers should move towards Open Access… however, a footnote added "Springer Nature and Elsevier ha[d] differing views with respect to this recommendation" (p. 9).

6.3 Institutions

More than two decades ago, Clifford Lynch wrote an essay on new genres of scholarly communication and the role of the research library. His words are as salient today as they were then:

> "This is a time for independent thinking, for intellectual courage, for leadership, innovation and pioneering. It is a time to recognize that we must move to a view that is broader than the print tradition and the published canon. Libraries can embrace or delay the emergence of the new genres; to the extent that they move to engage them, they have the opportunity to shape the landscape of scholarly communication for the next century, and their roles in managing it."[282]

Librarians do not merely passively accept transformations in scholarly communication: they incubate innovations, nourish novel genres, advocate for equity in dissemination and access, and serve as creators and publishers of new knowledge. These transformations raise—in the words of Lynch—both "tactical and strategic issues" that libraries must manage. These issues include the development and management of sustainable infrastructure. There are some good examples of this: Cornell University Library's Center for Innovative publishing currently houses arXiv, as well as Project Euclid and DPubS[283]; University of Michigan also has several initiatives, including Fulcrum. However, not all libraries have the financial resources or the expertise to develop these projects. Libraries are increasingly tasked with more responsibility, but very often no additional resources. Furthermore, the development of novel infrastructure must have the buy-in of the scientific community. For instance, social context was instrumental in the success of arXiv—the infrastructure worked because the community supported it. To be successful, it is necessary to have a community, a strong infrastructure, and service organizations that both legitimate and provide maintenance for the infrastructure.[284]

Libraries should also take a stronger stance vis-à-vis publishers. They should refuse to sign nondisclosure agreements when it comes to pricing, and to develop better negotiation mechanisms with publishers. Several institutions[285] and countries[286] across the world have cancelled their "big deal" subscriptions or have made selective subscriptions—focusing on journals that were sufficiently used by their communities.[287] SPARC maintains of list of these cancellations, which includes a number of Canadian institutions: the University of Saskatchewan, Université Laval, University of Calgary, Memorial University of Newfoundland, and the Université de Montréal.[288]

Journal negotiations are often a mix of ideological and financial concerns.[289] For example, the University of California (UC) noted two main drivers of their renegotiations with publishers: to reduce subscription expenditures and to invest in open access. The UC system sought to have full buy-in from librarians, professors, and the administrators noting that journal negotiations and cancellations are not without short-term challenges; however, "the long-term prospects for beneficial change outweigh the merits of attempting to cling to an untenable and undesirable status quo".[290]

One of the issues of the move towards digital publishing is long-term access to publications. This concern led several universities in Ontario to negotiate local load clauses in their publisher contracts which allows them to load licensed content onto Scholars Portal (a service of the Ontario College and Universities Libraries) to preserve the scholarly record.[291] At the Canadian level, CRKN has supported the Journal Usage Project,[292] which has provided 28 Canadian universities with detailed data on their journal usage to help them negotiate with publishers with precise information. Those actions help re-establish a balance of power between institutions and publisher to obtain fair and sustainable agreements.

One emerging type of agreement are so-called transformative agreements, which are contractual shifts away from subscription—i.e., reading-based—models to those focused on open access publishing.[293] Transformative agreements allow libraries and other organizations to move from payments for reading, to payments for publishing. Embedded in the ideology of open access, these agreements transform traditional copyright agreements (CC-BY recommended) and make contracts transparent.

There are two basic flavors of these agreements. One is the Read-and-Publish (R&P) "in which the publisher receives payment for reading and payment for publishing bundled into a single contract."[294] The payment for publishing is therefore included in the agreement rather than being handled by individual authors. This redirects costs originally allocated to subscriptions into publication costs. The goal is cost-neutrality; however, this has been challenged by several scholars[295]. The Publish-and-Read model (P&R), on the other hand, provides payment only for publishing, where reading is included at no cost. The model that is most beneficial depends in large part upon the publishing volume of the library or the consortium. In a consortial agreement, there can be considerable changes in the distribution of cost based on the selection of R&P or P&R, wherein for the latter the costs are borne primarily by the high-publishing institutions.[296] Countries with low publishing output have heralded transformative agreements, not the least because they are likely to be cost saving in the short-run.[297] However, one should question a model that does not anticipate or account for growth in publishing.

Transformative agreements are often only possible in the face of journal cancellations. The experience of Bibam—the Swedish library consortium, administered by the National Library of Sweden—is one example. Bibam saw a cost increase of 135% in OA publishing from 2014-2017. Given that the Swedish government had mandated OA by 2020, these costs were unsustainable alongside their subscription costs, which also saw a steady increase. Therefore, they negotiated with Elsevier for open access for publishers, reading access for all articles, and a sustainable price model for transitioning to OA. They were unable to reach an agreement and therefore cancelled in 2018. It was not until 2020 that a transformative agreement was reached, which will lead to an anticipated cost reduction of 1,700,000€ by 2022.[298]

It can be argued that the largest driver for transformative agreements has been Plan S[299]. Plan S provides provisions for hybrid publishing only in the context of a transformative agreement.[300] However, the transformative agreement must not last for more than three years; after that time, the agreement must be fully open access.[301] This policy has been a catalyst for change, but places the burden of these negotiations on the libraries and other scientific institutions. Several governments and funding institutions have also mandated forms of open access that functionally require institutions to adopt transformative agreements (to redirect subscription costs to APCs while maintaining a reading collection).

Given the burden that is placed on these individual organizations, many actors have been working together to collective create resources for libraries and other subscribing institutions. For example, Jisc—a non-profit institution in the UK which supports scientific organizations—established five criteria that must be adopted by Jisc supported institutions: 1) agreements must reduce and constraint costs, 2) agreements must be transitional, 3) agreements must aid compliance with funder mandates (e.g., green OA, CC-BY licensing), 4) agreements must be transparent (i.e., compliant with at least one of the cOAlition S Price Transparency Frameworks); and 5) content must be discoverable and agreements must support infrastructure improvements and include integration with services such as ORCID and CrossRef.[302] Approved agreements are registered with the Efficiency and Standards for Article Charges (ESAC) transformative agreement registry. The EAC is an international collaboration, run out of the Max Planck Digital Library with funding from the DFG[303]. This registry current contains more than 110 agreements, negotiated in 19 countries with 27 publishers.[304]

The Jisc objectives were made not in a vacuum, but motivated by several other complimentary projects. The Open Access 2020 (OA2020) initiative, for example, is also hosted by the Max Planck Digital Library and operates as "a global alliance of academic and research organizations committed to accelerating the transition of the current subscription system of scholarly publishing to new open access models, to ensure that research articles are published immediate open access and that the costs associated with their dissemination are transparent, equitable, and economically sustainable."[305] OA2020 has, among other activities, produced a statement from the 14th Berlin Open Access Conference (2018) which includes signatories from 37 countries. This statement provides a strong support for the retention of copyright by authors; complete and immediate open access; and temporary, transitional, and cost-neutral transformative agreements. OA2020 has joined forces with the African Open Science Platform, AmeLiCA, ScieLO, and cOAlition S in order to advocate for the withdrawal of financial support for paywalled publishing venues and reinvestment of those resources into open access publishing.[306] This advocacy is reinforced globally, for example in France by the *Jussieu Call* and *Joint Statement by the French National Research Funding Agencies in Support of Open Science*[307], in Brazil by the *São Paulo Statement on Open Access*[308], Projekt Deal in Germany[309], and the LIBER principles in Italy[310].

Transformative agreements, however, have come under increasing scrutiny in the past few months. For example, several open access publishers put forward a position statement, outlining concerns with these contracts:

> "Based on our assessment of several such agreements, we argue that they are not genuinely transformative and that their transformational potential is actually very low. Such models risk perpetuating current limitations on access, transparency and market competitiveness, while simultaneously facilitating excessive charges on the public purse. While they permit some legacy publishers to increase the fraction of OA content, they also increase the number of articles published in hybrid journals, lock subscribers into their current arrangements with publishers, and do nothing to improve price transparency. If such agreements allow publishers to continue their current pricing behavior, the long-term cost for libraries, higher education and research institutions will be much higher than they expect."[311]

Other scholars have also noted concerns that these agreements often lack "binding commitments" to full open access, limit access to particular parts of the publisher's portfolio, vary across borders, and perpetuate publisher control. [312] The aforementioned position statement, therefore, called for transformative agreements to (a) guarantee full transition to open access within a short and specified timeframe, (2) be a binding agreement that cannot be reversed or cancelled at the end of the contractual period, and (3) be inclusive all of all titles and legacy content.[313]

There are several concerns, in particular, with Publish-and-Read and Read-and-Publish models[314]. For the former, there is concern that P&R models are difficult to coordinate within consortia, disrupt workflows, and do not meet concerns for timing. In a simulation study, it was found that the P&R model would lead to large cost increases for high-publishing organizations and high cost savings for low-publishing institutions[315]. Due to this, high-publishing units would likely not accept the terms, which would lead to ad hoc arrangements with institutions that would threaten the more vulnerable institutions. This would, it is argued, be unlikely to lead to a transformation in terms of OA publishing. The authors suggest that R&P would be a more moderate route but would also not lead to substantial gains in OA publishing. They suggest a "smooth transition" that would stabilize both expenditures for libraries and publisher revenues, to avoid any massive financial changes whilst allowing for change from subscription to APC revenue and from content access to full open access.[316] It is anticipated that new models will be continually developed to meet these goals. A turn towards openness is inevitable; it is up to governments, research councils, and institutions to determine how to collectively make these transitions equitably and responsibly.

The university press also has an important role to play in the transformation of scholarly publishing. As discussed, there are several innovative projects in university presses, particularly regarding open access monographs. However, these initiatives need not happen independently. A 2014 report of the Library Relations Committee of the Association of American University Presses (AAUP)[317] noted that 95% of respondents saw the need for presses and libraries to work more closely in collaboration with one another. They overwhelmingly saw the function of libraries and presses as becoming duplicative as the library increasing engaged in publishing services. Collaborations will become an essential feature of a functioning university library and press in the coming years; for those institutions who have strengths in one, but not the other, consortia agreements will be critical.

6.4 Shaping the incentives

The recent European Commission report[318] provided several recommendations to key actors for improving the scholarly communication system and emphasized that most of those were social rather than technological. At the heart of their recommendations is a change in the research evaluation and incentives structures, acknowledging that the use of journal level-level indicators in tenure and promotion reinforce the role of for-profit publishers.[319] Therefore, they recommend to universities and funders—as well as to researchers, who are generally the ones doing the evaluations—to go beyond bibliometric and journal-level indicators and recognize the spectrum of forms that dissemination of knowledge can take. One of the key structural elements in the research evaluation system is the journal impact factor[320] which, along with other journal lists,[321] shapes evaluations in many countries.[322] Such journal-level indicators and lists strongly orient researchers' publishing decisions, and those should be removed from the bibliometric toolbox given their well document adverse effects.[323] These indicators could be replaced by others which would change behavior in a progressive way, such as indicators about openness or diversity in the workforce.[324]

In this context, the current COVID-19 crisis highlights the fact that indicator-based research policy has limitations when it comes to solving urgent, practical research problems. Getting rid of the journal impact factor would change the dynamics of the system for everyone, even for young researchers who, post San Francisco Declaration on Research Assessment (DORA), feel uncertain as whether alternatives to the journal impact factor could even be worse.[325] The only organisations that are not tied to journal impact factors are research funders, whose stakeholders—governments and population—would rather have researchers be evaluated through their capacity to solve economic, health, or social issues rather than by compiling their journal impact factors. Therefore, it is funders that can shape the landscape of scholarly publication; bring a better balance between public and private sectors; and ensure openness in infrastructures, standards, and access. This will only be done which a change in how researchers are accountable for the work they do; with a shift from a result-based assessment—mostly through publishing papers—to assessments that takes into account the uncertainty in research, and that incentivizes research for the common good.

7. Concluding remarks

True revolutions are rare in scholarly communication. Even with the printing press and the Internet, there has always been a "balance between continuity and discontinuity [in which] new media technologies evolve out of older media while preserving underlying communication formats and practices [and] old practices seem to fold into new technologies and shape them continuously."[326] The invisible college continued to exist and letters circulate, even after the rise of the printing press. Journal articles were moved as exact replicas from the print to the digital environment, without taking into consideration any of the new affordances of a globally digitized world. We have only recently begun to shed the limitations imposed by this old world (e.g., page limitations) and embrace the new affordances (e.g., hyperlinks, videos, sematic linking).

The move to open access has similarly embraced this tension between continuity and discontinuity with libraries are creating infrastructures for dissemination and negotiating new forms of agreement with content providers. Such initiatives are explicit manifestations of the time that it takes to shift practices and infrastructure to meet the challenges and opportunities of these revolutionary technologies. Scholarly journals are themselves changing. The combination of adding machine-readable metadata, publishing online, and linking to unique document identifiers allows us to create an interconnected web of scholarly content and truly realize the semantic publishing practices that were envisioned decades ago.[327] As this work is freed from corporations and standardized with particular indexing requirements, we will finally see a true, multi-modal, web of knowledge.

Revolution can also come through global events. As we were writing this review, the COVID-19 pandemic gripped the world. The initial socio-economic consequences are dire and apparent, yet it will take years of research to fully grasp the impacts of the pandemic on society. The ecosystem of science is at the heart of the pandemic: as a social institution, it shares the same impacts as the rest of society. However, science is also being called to provide solutions for the pandemic, amidst the barriers imposed by the pandemic.[328] This is laying bare many of the issues in scholarly communication and will accelerate change and potentially change the trajectory for future innovation.

The current events remind us of the importance of open and efficient infrastructures for disseminating research results. For-profit publishers reacted by making COVID-19 and coronavirus research openly available during the pandemic.[329] This "temporary" policy, however, was an implicit admission that the normal situation—locked access—is an obstacle to the advancement of knowledge.[330] It also suggests that COVID-19 is a more important disease than cancer or cardiovascular disease, for which opening would not be necessary. If opening research on coronaviruses accelerates the production of knowledge in this area, why not open research on all health issues—other than for purely economic concerns?

We are also reminded that there are still barriers to knowledge, which transcend countries, disciplines, and languages. The pandemic demonstrates that private, for-profit, research dissemination infrastructures, which have not made openness of science their core mission, are hampering the development of science and work against the good of society. The majority of the journal literature remains locked behind a paywall for those—researchers, practitioners, funders, and general public—who cannot afford high subscription costs. The Zeitgeist for openness is strong; however, we must move from mandates and manifestos to the establishment and support of collectively-owned infrastructure. This will allow governments and scientific organizations to innovate according to the ideals of science, rather than that of business. Such a shift in ownership and a redistribution of costs will allow for science to innovate in several ways: broadening participation, harnessing creativity across the knowledge space, and ensuring equity and justice in the creation and dissemination of new knowledge.

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