E-Revista de Estudos Interculturais do CEI–ISCAP
N.º 10, maio de 2022

PRODUCING AND COMMUNICATING SCIENTIFIC KNOWLEDGE: CURRENT CHALLENGES IN THE ACADEMIA

A PRODUÇÃO E COMUNICAÇÃO DO CONHECIMENTO CIENTÍFICO: DESAFIOS ATUAIS

Marco Faria[1]
Centre for Intercultural Studies – Polytechnic of Porto, Portugal
*marcoflmachado@gmail.com

ABSTRACT: Since the early days of scientific publishing, scholars chose journals to share their work and trusted publishers with a key role in the diffusion of knowledge. In time, the revenues, profit, and prestige of commercial publishers grew, so did their prices and control over the market. Today, the scholar publishing market is concentrated in a few major publishing houses and scientists are victims of a numerical and statistical assessment. In fact, the expansion of information and communication technologies, with the Worldwide Web, enabled ultra-fast and effective communication. However, the academic community did not seem to capitalise on these developments. This paper analyses the current state of the scholar publishing market, the misuse of the impact factor, and presents the benefits of Open Science as a systemic effort towards a more reliable, effective, and equitable knowledge system.
KEYWORDS: Scientific knowledge; scholarly communication; scientific publishing market; impact factor.

[1] Marco Faria received an MA in Intercultural Studies for Business from Porto Accounting and Business School. Currently a Junior Researcher in the Centre for Intercultural Studies of the Polytechnic of Porto. His research interests include Epistemology, Knowledge and Innovation Policies, and Political Economy.

RESUMO: Desde os primórdios da publicação científica que a comunidade académica escolhe as revistas para partilhar o seu trabalho e confia nas editoras com um papel chave na disseminação do conhecimento. Ao longo do tempo, os lucros e o prestígio das editoras comerciais cresceram, assim como os preços e o seu controlo sobre o mercado. Atualmente, o mercado das editoras académicas é um oligopólio e os investigadores são vítimas de uma avaliação meramente numérica e estatística. O alargamento das tecnologias de informação e comunicação permite hoje uma comunicação rápida do conhecimento, mas a comunidade académica parece ainda não ter aproveitado estes desenvolvimentos tecnológicos. Este artigo analisa o estado atual do mercado editorial académico, o uso indevido do fator de impacto como avaliação da investigação, e apresenta os principais benefícios da Ciência Aberta como um movimento que visa alterações profundas ao nível institucional para criar um sistema de conhecimento científico mais fiável, eficaz e justo.
PALAVRAS-CHAVE: Conhecimento científico; comunicação de conhecimento; mercado da publicação académica; fator de impacto.

1. Introduction

Before the establishment of scientific academies in the 17th century, such as the Royal Society of London, communication between scientists was only accomplished through the sending of letters or occasional meetings and seminars, which meant they must necessarily know each other prior to the exchange of experiences. Consequently, the wide dissemination of knowledge was hindered although it was known by then that sharing and accumulating partial elements of knowledge was key to the progress of Science (Rentier, 2019).

In 1665, the first issue of the Royal Society's Philosophical Transactions, still active to this day, was published, with the commitment to regularly publish reports on scientific advancements and build a systematic and structured recording and archiving of scientific knowledge. Paired with the invention of printing two centuries earlier, scientific journals allowed for a faster and wider dissemination of knowledge. Since then, the importance of journals has increased considerably. After coexisting with previous forms of communication, such as correspondence, they became the main media for diffusing new research results during the beginning of the 19th century and consolidated that position in the 20th century. Scholarly periodicals also contributed to the professionalisation of research and scientific activities and to the formation of new disciplines through a process of specialisation (Larivière et al., 2015).

Centuries after these advancements, the academic community entered the era of computers and their applications in the field of communication, with the Worldwide Web, born at the end of the 20th century. Digital transformations, mainly the expansion of the Internet, paired with the boost of funding, led to a growing production of knowledge in the academic field. Consequently, this meant a flouring of business opportunities for commercial publishers - as more knowledge was produced, more raw material there was to be published and, therefore, potential for profit. In turn, private publishers formed huge multinationals through acquisitions and large-scale buyouts that have led to the near extinction of smaller publishing houses. Larivière et al. (2015) state that scientific literature is concentrated in a few major publishing houses – a monopolistic situation known as oligopoly. This work aims to debate current challenges in the academia – specifically the peculiar market conditions of scientific publishing and the evaluation of researchers, present Open Science as a movement deeply transforming scientific practices and discuss the benefits of adopting Open practices.

2. Current challenges in the production and communication of scientific knowledge

2.1. Scientific publishing market

In the original model of scholarly communication, the faculty produced the work to be published and academic societies and university presses were responsible for the entirety of the publishing process, from editing, to printing and even distribution of the journals. Then, the university would buy the published work with inflated prices to subsidise those societies, providing literature for further research and teaching (Lyman & Chodorow, 1998). Subsequently, those societies started subcontracting the more technical stages of the process to commercial publishing houses, such as printing and distribution, and only handling the editing (selecting the articles, organising the peer review process and the final decision to publish). Those private publishing houses, realising the potential for profit, thrived to the point of taking on all the publishing (Rentier, 2019).

By the mid-1990s, commercial publishers accounted for 40% of total journal output, while scientific societies accounted for 25% and university presses 16% (Tenopir & King, 2000). Similarly, the United Kingdom (UK) Office of Fair Trading (OFT), measuring several publishers' shares on the market for the 1994-1998 period, showed that a single publisher, Elsevier, accounted for 20% of all Web of Science-indexed (OFT, n.d.). Lyman and Chodorow warned in 1998 that scientific literature was being monopolized by multinational publishing conglomerates.

Based on all journals indexed in the Web of Science from the 1973-2013 period, Larivière, et al. (2015) analysed the scientific literature market, showing the evolution of major publisher's share on this market over time.

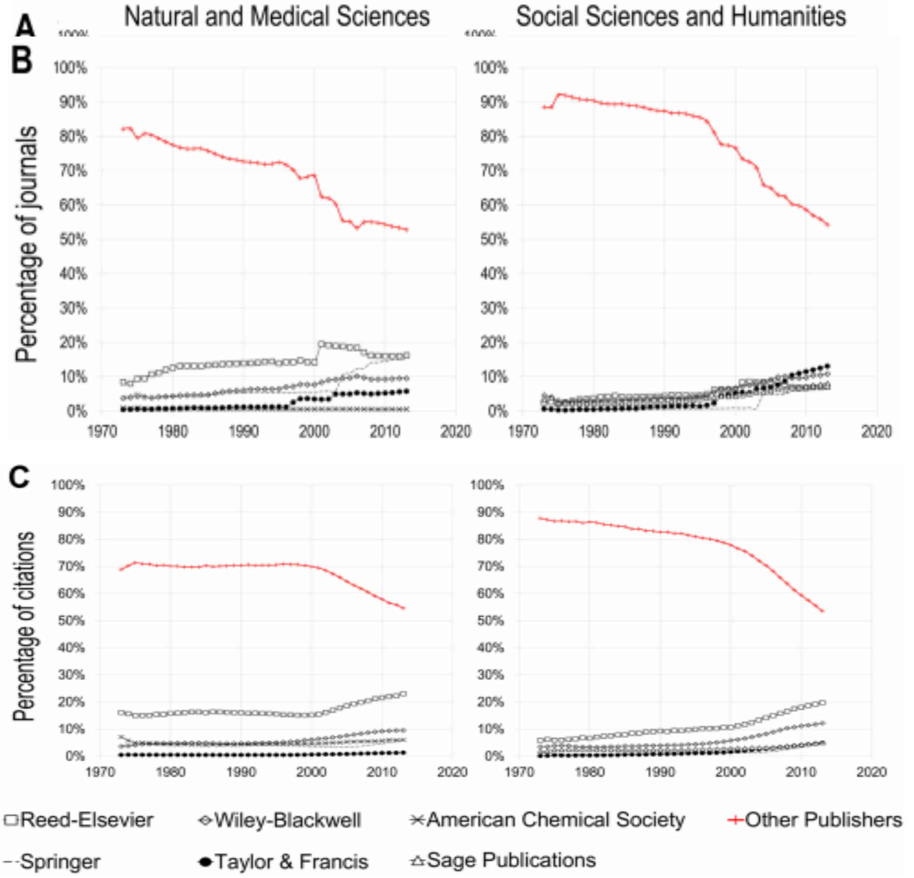

Figure 1. Percentage of Natural Medical Sciences and Social Sciences and Humanities papers published from 1973 to 2013. Reprinted from "The oligopoly of academic publishers in the digital era" by V. Larivière, S. Haustein and P. Mongeon, 2015, *PLOS ONE*, *10*(6), p. 4. Copyright 2015 by Larivière et al.

The study groups scientific publications in two major disciplines: Natural and Medical Sciences (NMS) and Social Sciences and Humanities (SSH). Figure 1A presents the proportion of scientific papers published by the top five publishers and papers published by other than those of the top five. Figure 1B presents the proportion of journals published, and Figure 1C shows the publisher's share of citations received from its journals and papers. The study considers 'top five' major publishers those with the highest number of scientific documents published in 2013.

In both broad domains of scholarly knowledge, since the advent of the digital era (mid-1990s), the drop in papers, journals, and citations' share from smaller publishers (other than the five major publishers) is striking. The data is similar for both disciplines. The percentage of NMS papers by major publishers increased from 30% in 1996, when entering the digital era, to 53% in 2013. Still in the domain of NMS, just three publishers accounted for more than 47% of all papers in 2013. Concerning SSH, the top five accounted for just about 15% of the published output in the mid-1990s. Then, the concentration increased even more abruptly when compared to NMS and, by 2013, 51% of all SSH papers were published by journals owned by one of the five major publishers. Similar trends are observed in the number of journals published and the publishers' share of citations received, although the major publishers enjoy a slightly shorter share of citations than what is to be expected since they publish more scientific literature. The fact that big publishers account for more papers than journals published suggests they publish a higher number of articles per journal. More recently, data from 2019 by Bosch et al. (2019) show the five major publishers, Elsevier, Springer, Wiley, Taylor & Francis, and SAGE represent 59% of the titles indexed.

To develop the subject of citation rates, the same study provides relevant information on changes in papers' citation rates for journals which have changed from small to big publisher and vice-versa. Interestingly, there is no effect in journals moving from big to small publishers in both periods. In SSH, there is no discernible effect in the citation rates from a journal after switching from a smaller to a bigger publishing house. This suggests journals changing to major publishers does not necessarily mean, on average, that they will achieve a bigger scientific impact. While in both domains the study shows that scientific literature became more concentrated on top commercial publishers, with figures around 50%, there is a distinction between NMS and SSH. In the former, the literature was kept less dependent on those publishers. One aspect that might have contributed to the less degree of concentration in NMS is the size of scientific societies in this discipline. For example, the American Chemical Society was the fourth most prolific publisher in 2013 in the NMS. Additionally, the American Physics Society and the American Institute of Physics each accounted for 15% of the papers in that field. The strength and size of scientific societies, 26 which publish a substantial number of scientific papers in their field, and also Open Access agreements such as the Sponsoring Consortium for Open Access Publishing in Particle Physics are likely to make the field less profitable – and therefore less interesting for commercial publishers. In biomedical research, the share of the major publishers decreased from 49% in 2009 to 42% in 2013 with the emergence of new publishers committed to Open Science practices, such as the Public Library of

Science, responsible for the PLoS ONE journal. This suggests that academic societies well established in the publishing market adapted better to the digital era. In contrast, social sciences are more fragmented: economics, communication, sociology, anthropology can all be considered social sciences but there is no large scientific society that groups these researchers and takes on the publishing business itself. There are many different associations for each disciple which are then often divided into specialities, leading to smaller and more decentralized societies.

Results show commercial publishers benefitted from the digital era as they consolidated steadily their shares in the scientific and technical publishing market, which revenues are comparable to the film or recording industry, but far more profitable, having now the major share of scientific literature published. As expected, with such control over the market, profits increased for such publishers. Publisher Reed-Elsevier made £992 million in profits on revenue of 2.6 billion £ in 2019, with a profit margin of 37.1%, expecting to grow even further in 2020. Other commercial publishers obtain similarly very high profit margins (Larivière et al., 2015).

To the UK's OFT (n.d.), the primary concern is that the average price of journals has risen well above the rate of inflation and is considerably higher than those of non-profit journals. Prices of scholarly journals started rising faster than inflation during the 1970s and have been rising nearly four times faster than inflation since 1986 (Suber, 2015). The Library Journal publishes a yearly review of periodic pricing using all papers indexed in the ISI and several other academic databases and repositories. From 2017 to 2019, the yearly average change in the cost of journals was 6% and this percentage is expected to remain constant for 2020 (Bosch et al., 2019).

To justify the increase in prices and profit margins, Reed-Elsevier directs the argument to the increase of variable costs, such as investment in developing electronic methods for delivering journals. However, the OFT is not persuaded by these arguments because the digital era actually made the costs of printing and distributing physical journals substantially shorter and even increased potential revenues for publishers (OFT, n.d.). The costs of publishing a journal can be divided in first copy costs and marginal subscriber costs. First copy costs are associated with the producing of a single issue, independent of the number of subscribers. For journals, it includes the cost of managing an editorial office – wages and secretarial support for the editors who handle and evaluate the paper submitted by the authors, copy-editing, and typesetting the manuscripts. Those do not increase or decrease regardless of the number of subscriptions – it is the cost of producing an issue. Marginal subscriber costs do, however, increase depending on number of subscriptions. They include printing, paper, shipping, postage, distribution and managing subscriptions. Before the digital era, every journal that was published and sent to subscribers meant that marginal costs were, necessarily, higher for each unit. With the digitalization of papers, journals submitted online or subscribed electronically by libraries or institutions mean that papers can be accessed by many researchers simultaneously without representing an increase in marginal costs, for each unit does not need to be produced each time it is accessed. Every subscription sold is then pure profit for the publishers because there are no costs associated with additional units (Bergstrom, 2001). For a traditional publisher, in order to make money, its revenues must first cover a multitude of costs: paying writers for the articles, employing editors to shape and check the articles, and the distribution of the finished product to subscribers. Successful magazines typically profit around 12-15% (Buranyi, 2017). At first, the business model for scientific journals looks the same. However, publishers in this market manage to evade most of those costs. Scientists create the work, mostly funded by public money, and offer it to publishers; then, the publisher pays scientific editors to judge whether the submissions are worth publishing, but the most important work, evaluating scientific validity and the experiments, the process of peer review, is done by scientists on a volunteer basis (Rentier, 2019). After evading those costs, publishers sell the product back to government-funded institutions and university libraries only to be read by scientists, who collectively created the product, with astonishing profit margins higher than Google or Amazon. It is as if the governments invested on the work only to the profit of some publishers and not the public (Buranyi, 2017).

These peculiarities that characterize scholarly publishing allow for an increase of profits for publishers. In addition to authors supplying their goods without compensation, the readers are also often isolated from the purchase. That is, despite the ultimate user being the reader, academic libraries usually make the purchase. Libraries contribute 68% to 75% of the publisher's revenues and their purchases are not necessarily decided by information needs but rather through debate between librarians, budgetary committees, and faculty members. The increase in subscription prices creates pressure in ever-decreasing budgets and due to big publisher's control over the market, libraries are often left with no other choice but to cancel subscriptions, for each paper cannot be replaced – copyright transfer agreements often prohibit authors from submitting their work to other journals, making each paper unique and irreplaceable (Larivière et al., 2015). Even the richest university library in the world, Harvard, claims to be no longer capable of affording all its journal subscriptions (Schmitt, 2015).

Many university libraries welcome big commercial publishers' package deals offering electronic access to a large portion (or all) of their journals in opposition to subscriptions to individual journals – common in the print era. This means that, despite journals being differentiated, they are packaged as a single product supplied electronically. While it might seem like a solution for libraries to save money, it leads the market towards publishers with big portfolios and journals owned by smaller publishers cannot compete with such portfolios. Moreover, competition through price is not relevant in this market. Competition among journals is based on quality rather than price and since many journals have significant reputation in their subject matter, they can be regarded as markets on their own. There is often an unwillingness of institutions and libraries to substitute them with cheaper journals. In practice, this means that if an established journal of a certain field increases its price, it is the less-established journal of the same field that is cancelled, so that the subscription of the prominent journal can be maintained. Hence, publishers can increase their market share by raising the prices of certain journals, unparalleled in other business sectors (OFT, n.d.).

Despite new journals entering the market frequently, it is very difficult for them to secure a solid reputation. For researchers, highly regarded journals offer a bigger incentive than less prestigious ones because they are supposedly more frequently read and cited. Researchers want to publish in leading journals to establish themselves on their fields, which in turn creates a vicious circle. Already prestigious journals attract most able researchers (either authors, editors, or reviewers) to enhance their status, which makes it harder for newly created smaller journals to compete. Additionally, most libraries are under limited budgets and are unable to subscribe to a new periodical without cancelling an existing one, even more so if it is a well-regarded one or part of a before-mentioned package deal (OFT, n.d.).

Ever since 1665, in London and Paris, in the early days of scientific publishing, scholarly journals do not pay the authors for their articles. Instead of books, scientists chose journals, they were timelier, allowed to quickly share new work with the world and to establish claims to priority over other scientists. For readers, journals were better for keeping up to date with the most recent work. Scientists were rewarded with these strong, intangible ways and accepted these benefits as payment from the publishers which, such were the costs, could not really pay them much (Suber, 2015). Publishers played a key role in the diffusion of journals: it was not possible to disseminate knowledge in any other way. Over time, journal revenue grew but authors continued to hand over the product of their intellectual labour to publishers for free. Simultaneously, with the unbearableness of prices, the internet emerged as a possible alternative – certainly, it can make researchers independent of the most technical stages in charge of publishers. However, not only did that not happen but prices continued to rise, despite the costs for the publisher decreasing, and the publisher's prestige reached new heights. This begs the question: why does the scientific community still collectively rely on publishers? At least enough to supply them with the labour with which they will profit – with profit margins similar to pharmaceutical powerhouse Pfizer (42%) and bigger operating profits than Apple – and abandoning their remuneration rights along the way, a common practice for publishers (Rentier, 2019). Publishers handle the process in the bigger picture but, in reality, scientists are responsible for the editing, and it is the scientific community that performs peer review, so publishers do not actually add value in this process (Larivière et al., 2015). Scholars play the roles of authors, referees, editors, and readers.

Journals that attract recognised scholars are more frequently read and cited. Libraries will subscribe to journals the more they are read, for the demand is bigger, and more scholars will want to write for a journal widely available in libraries for it increases their opportunities of being cited. The stature and prestige of commercial publishers does not reflect any major input the publisher provides, but, instead, their position in the market. Publishers have the symbolic function of allocating academic capital: being published in certain journals brings recognition and opportunities to researchers (Larivière et al., 2015). Researchers are evaluated according to the journals they publish on. Since the quality of those journals is dictated by a citation-based metric, the impact factor, researchers are ultimately being evaluated by the impact factor of those journals. Decision-making process of funding, promotion, and appointment relies on the impact factor.

2.2. The issue of the Impact Factor

The concept of journal impact factor was first developed by Eugene Garfield in 1955 in *Science* as a measurement of the value of a journal using the average number of citations over a specific period of time (Garfield, 1955). While selecting journals for the Science Citation Index (SCI), in need for a simple method to compare journals, Garfield created the journal impact factor. A journal's impact factor in a given year is the ratio between the number of citations received in that year for articles published in the two preceding years and the total number of articles published in that journal during the last two years. The choice of two years was to keep the measure current (Garfield, 1999).

The impact factor was created as an honest measure to compare journals, but Garfield himself (Garfield, 1999) has written about the controversy it has created because of its misuse. Albeit there are other bibliometrics (citation-based metrics), the impact factor has evolved to become the most used measure to evaluate the quality of research papers, the researchers who write those papers and even institutions (Saha et al., 2003).

The value of the impact factor is affected by subject area. Patterns of citation differ depending on subject fields. For instance, most citations of articles in the field of medical sciences occur soon after their publication, falling within the window of the impact factor, whereas in social sciences, most of citations tend to fall beyond that window (Adler et al., 2008). In highly dynamic research fields, such as biochemistry and molecular biology, published reports rapidly become obsolete. As such, citations on those articles are usually very up to date, contributing for the impact factor of all cited journals. This can mean that scientists in an apparently less citable field (in terms of impact factor) may be at a disadvantage when compared with colleagues from other fields, since they lack access to journals with higher impact factors (Seglen, 1997). The variation can be such that a top journal in a certain field can have a lower impact factor than the bottom journal in another (Amin & Mabe, 2000). Examining the database of citations in mathematics journals, Adler et al. (2008) concluded that 90% of citations fell outside of the two-year period, this means that the impact factor was based on 10% of the citation activity on that field.

The phenomenon of multiple authorship is also related with subject area and strongly affects the impact factor of a journal. The average number of collaborators in social sciences is about two per paper, while in life sciences that average is over four per paper. Given the tendency of authors to cite their previous work, there is a linear correlation between the number of authors of a paper and its impact factor. Consequently, impact factor should only be used for comparing journals in the same subject area (Amin & Mabe, 2000).

The size of the journal must be also considered for year-to-year variability which does not necessarily mean inconsistent quality. The impact factor is calculated as an average and is susceptible to variation due to statistical effects – for example, the number of items being averaged. As such, journals publishing fewer articles have a smaller sample size, and consequently bigger variations are expected. Journals who published less than 50 articles annually experienced a change of almost 50% from 2002 to 2003 (Adler et al., 2008). That does not mean that smaller journals are more inconsistent with their quality, but just that the sample size is smaller. Caution must be exercised to avoid inferring too much from changes in impact factors depending on the size of the journal. To smooth these steep statistical variations, one solution would be, for example, to expand the measurement window from the two-year frame to five years.

The misuse of the impact factor is also clear because it assigns the same score to all the articles in the same journal. Articles contribute unevenly to the journal's citations, and multiple papers have demonstrated the skewness of citation data. Seglen (1997) argued that in a journal "the most cited half of the articles account for nearly 90%" of that journal's citations and just 15% of the most cited articles represent half of a journal's citations. This means that few articles can determine the impact factor of a journal and that other articles receive credit even if they are uncited. More recent findings (Rentier, 2015) using the 2014 impact factor for the journal Nature (about 41.4) show similar results. From all the 1,944 articles published in the journal in 2012 and 2013, only 75 articles provided 25% of the journal's citations and just 280 accounts for half the total citations. This means that journal impact factors correlate poorly with actual citations of articles and are not statistically representative of individual journal articles.

The impact factor is only calculated for journals covered by the Web of Science, citations in journals not included in this database do not count for the calculation of the impact factor and also citations in books are left out – a substantial part of scientific output in many research fields, such as arts and humanities, is published in the form of books. The coverage of fields is also not equal, meaning there are fields more represented in the database than others. If citations of journals not included in the database do not count for the calculation of the impact factor, then the impact factor of a journal will be proportional to the database coverage of its research field. Journals from underrepresented fields will receive smaller impact factors for they will not receive many citations from journals indexed in the Web of Science (Kumar, 2018). The database is also biased towards English language journals, which means that journals not published in English will likely receive fewer citations (Rentier, 2015), especially from journals indexed in the database since most citations to papers in other languages are given by papers in the same language (Kumar, 2018). Other criticisms of the impact factor include technical shortcomings in the formula itself and its permeability to any inaccuracies or misprints in the references (Kumar, 2018; Seglen, 1997).

The impact factor relies on the theory that the importance of a journal is accurately measured solely by its citations' frequency. However, the ultimate goal of science is the improvement of quality of life for all people and not all of the journal's end users are researchers (who will cite the paper and 'cast a vote' for the journal); there are also practitioners who will translate research findings for the public good. For instance, a journal's influence in clinical medicine is dictated by its importance to practitioners, who most of them will not publish an article and cite the journal. Citation frequency, the impact factor, reflects a journal's importance for researchers, and even then, like it was shown previously, it is very much questionable. The opinions of both practitioners and researchers are relevant for judging the importance of a journal, as such is the validity of solely placing a journal's importance upon the impact factor might not tell the whole story (Saha et al., 2003). Furthermore, it erroneously implies that the weight of each citation is the same in a paper, and that every citation is inherently praising someone's work.

Naturally, those who fund scientific research, institutions, and governments, want to assess the quality of their investments. The belief that the impact factor is more accurate is because it presents a single number instead of a complex judgement, and it is thought to eliminate ambiguities. However, the abovementioned criticisms show us that the impact factor is easily affected by other components other than quality and that this objectivity is deceptive. In ambitioning a more transparent evaluation, institutions created a culture of numbers in which they believe that by using an algorithmic assessment of statistical data they will make more just decisions (Adler et al., 2008).

Although the use of the impact factor and other similar metrics is an important tool, it must be interpreted with caution and its usage combined with other methods. The impact factor is useful as a citation measure to assess the influence of a certain journal within its subject area, but to extend its purpose to the authors is wrong, for the information it provides is too vague (Adler et al., 2008; Rentier, 2019; Seglen, 1997). Ultimately, using the impact factor means using citation-based statistics to rate journals, papers, researchers, and programs. For journals, the impact factor is reductive, there are many confounding aspects when judging journals solely by citations. For papers, the misuse is often linked to substituting the actual citation count of an article by the impact factor of the journal in which it is published, and as we already know, a higher impact factor does not necessarily mean a higher citation count. For scientists, the impact factor is being used explicitly not just to evaluate their papers but themselves and their careers. For instance, there is the belief that a paper published in journal A, with a greater impact factor that of journal B, is superior than an article published in journal B and consequently author A must be superior to author B.

Institutions are increasingly recognizing the shortcomings of journal-level metrics and exploring alternative metrics in evaluating research. In 2012, a group of editors and publishers of scholarly journals met at the Annual Meeting of the American Society of Cell Biology in San Francisco and released a declaration recommending institutions to rely their research evaluation for promotion and tenure on the research content instead of the impact factor and other metrics. The Declaration on Research Assessment (DORA, 2012) states:

> The Journal Impact Factor is frequently used as the primary parameter with which to compare the scientific output of individuals and institutions. […] it is critical to understand that the Journal Impact Factor has a number of well-documented deficiencies as a tool for research assessment. […] we make a number of recommendations for improving the way in which the quality of research output is evaluated. Outputs other than research articles will grow in importance in assessing research effectiveness in the future, but the peer reviewed research paper will remain a central research output that informs research assessment. […] These recommendations are aimed at funding agencies, academic institutions, journals, organizations that supply metrics, and individual researchers.

DORA's recommendations are clear: those institutions and organizations should stop using metrics such as the impact factor in the decision-making process of funding, appointment, and promotion considerations; research should be evaluated on its own merits rather than based on the journal in which it is published; the academic community should capitalize on the opportunities provided by online publication and explore alternative indicators of significance and impact. As of December 2021, more than 19,000 organizations and individuals have signed the declaration and committed to its recommendations. Several U.S and European institutions committed to the DORA's recommendations and explicitly adopted open practices in promotion and tenure evaluations. For instance, in 2014, Harvard's School of Engineering and Applied Sciences encouraged the faculty to archive their articles in the university's open repository as part of the promotion and tenure process (Harvard Library, 2016). Two years after, the University of Liège went further and required publications to be uploaded to the university's open repository for researchers to be even considered for promotion (Rentier, 2019). In 2015, the UK's system for assessing research quality in higher education institution rejected the use of the impact factor to evaluate researchers and recommended institutions to explore different quantitative and qualitative indicators of research impact and to recognize sharing of diverse research outputs (Wilsdon et al., 2016).

In conclusion, DORA (2012) is part of an international movement that aims to shift the evaluation of research and researchers from bibliometric indicators to a more holistic and transparent approach. When evaluating publications, scientific content should be the prioritised criterion. Journal-based metrics, such as the Impact Factor, should not be used to measure the quality of an article. By emphasizing that evaluation of research publications should not be dependent on the publication channel and that a broader range of outputs should be considered, DORA (2012) advocates for Open Science.

3. A Shift in Paradigm: The Rise of Open Science

The European Commission (2015) defined Open Science as: "a new approach to scientific development, based on cooperative work and information distribution through networks using advanced technologies and collaborative tools" that aspires to "facilitate the acquisition of collective knowledge and to encourage the emergence of solutions based on openness and sharing". The ultimate goal is to accelerate the progress so that discoveries are turned into benefits for all, by guaranteeing that all scientific outputs are publicly available, easily accessible, and discoverable for others to build upon (Masuzzo & Martens, 2017).

Watson (2015) wondered "isn't that just science?". In fact, the premise of science based on a collaborative effort, building upon results of others, is not new. The scientific revolution of the 17th and 18th centuries only cemented and formalized the belief that truths are discovered by building upon previous findings. Like Isaac Newton stated in 1675 to his fellow scientist Robert Hooke: "If I have seen further, it is by standing on the shoulders of giants". While creativity and intuition are often individual contributions, validation of scientific findings is only achieved through collaborative efforts – collective and critical inspection and analysis can refine, improve, or reject hypothesis. This is the basic principle of science – conclusions formulated and validated by the efforts of many takes prominence over personal statements. In this regard, Open Science is the ultimate realization of science. Science has depended on an open process for centuries, but to various degrees. The beginning of scholarly publications, with 'Philosophical Transactions', was intended to diffuse knowledge as widely as possible. Today, with the transformations associated to the digital era, knowledge can be shared to a larger audience and allow for a true fulfilment of the scientific method.

The idea of Open Science relies on the notion that knowledge is a public good and that publicly funded universities and granting bodies have a moral duty to make academic research output available without barriers (Masuzzo & Martens, 2017; Rentier, 2019). In the current situation, scientific knowledge, as the product of research, is still far from being considered a public good. Knowledge is produced by research and disseminated through publications, which, as their name suggests, are intended to make it public. In fact, the scientific community does all the work – that is, the researcher prepares a project, designs the research, submits it to a funding entity, carries out the investigation, writes the paper(s) and submits it free of charge. The researcher resorts to the publisher merely to make the findings public, but in this process transfers to the publisher the rights to the work (Rentier, 2019). Suber (2015) calls this permission barriers (copyright and licensing restrictions). Obviously, if the scientists request a service by a third party, that service must be paid. But it is also obvious that payment should be proportional to the service provided. It is in this stage when knowledge becomes exclusive, for its rights are transferred to the publisher and the access to it is behind a paywall (pay-per-view, subscriptions, among others) expensive to all parties involved. Suber (2015) describes this as a price barrier.

In summary, the movement of Open Science was born almost as a counterculture to the closed system that emerged during the 20th century that meant: the majority of research papers being behind a paywall (Khabsa & Giles, 2014), reproducibility of findings being hindered by the lack of reporting (Begley & Ioannidis, 2015), lack of availability of research data and software (Ince et al., 2012), a lack of transparency in a slow peer review process (Björk & Solomon, 2013) and moral and ethical concerns (Masuzzo & Martens, 2017; Rentier, 2019).

3.1. The Four Pillars of Open Science

Open Science can be defined as a continuum of practices, starting at the most basic level of openly sharing publications to the highest level of sharing research data in real time (McKiernan et al., 2016). It evokes many different concepts and covers different fronts from different degrees of application. This diversity of concepts makes the term 'Open Science' an umbrella term used to cover any kind of change towards more accessibility and availability of scientific knowledge (Björk & Solomon, 2013; Masuzzo & Martens, 2017; Rentier, 2019).

Masuzzo and Martens (2017) distinguish four thematic pillars in which Open Science relies on to enhance openness: Open Access to papers, Open Data, Open Code, and Open Peer Review. In this section, a brief introduction will be provided and the benefits of adopting these practices will be addressed, both for researchers and for the improvement of science.

Open Access. Open Access movements in the 1990s originated due to the feeling of injustice amongst researchers of the closed system of publishing. That was the first attempt to change the way science was shared and make the system independent from the unilateral constraints of publishers. The first effort was put forth by the physicist Paul Ginsparg when he created arXiv – an electronic repository for prepublications of scientific articles (Lancaster, 2016). Promptly adopted by other physicists, mathematicians, and computer scientists, ArXiv is built on the principle of free publication and free printing. Hoping to threaten the power of big publishers in the long-term, Steven Harnad suggested an Open Access model of publishing in 1994 – the Green Open Access model. In this model, authors submit the articles in a traditional way to publishers but then deposit the articles in digital archives as soon as they are accepted by the publishers (Rentier, 2019).

Open access literature is available online and is free of charge and of most copyright and licensing restrictions (removes both price barriers and permission barriers). Moreover, it is compatible with copyright, peer review, revenue and even profit, quality, career advancement, indexing, and all features of the conventional scholarly system. The only difference relies on having no costs for the readers and no barriers to access (Suber, 2015). Open Access initiatives aim to create a new 'Open Access' business model for scientific publishing or, in the absence of this, institutional repositories where all scientific publications are to remain freely accessible. These principles are transposed into two main paths: the 'golden road' and the 'green road' of Open Access.

Under the golden road, journals directly provide free Open Access to their articles (Organization for Economic Co-operation and Development, 2015). The golden road includes institutions implementing policies to require their researchers to deposit a copy of all their research outputs in Open Access repositories and encourage them to publish Open Access journals. The 2017 UNESCO Recommendation on Science and Scientific

Researchers calls for Member States to establish publishing in Open Access journals as the norm for all scientific publishing and to take measures to ensure "equitable and open access to scientific literature, data, and contents, including by removing barriers to publishing, sharing, and archiving of scientific outputs" (UNESCO, 2017).

The green road centres on the self-archiving of articles published through traditional channels, where authors provide access to their own published articles by making their own e-prints free. In this model, coined by Stevan Harnad in 1994, authors submit their articles in the traditional way to a publisher, through all the usual stages (peer review, modifications and additions requested, signature of contract, acceptance of conditions, waiver of copyright, possible embargo period, etc), and in parallel, they simply deposit them in the digital archive of their institution. Harnad was aware that this approach would not immediately change publisher's business models, but he hoped that it could undermine the foundations in which the system relies on and change it in the long run (Rentier, 2019).

Open Peer Review. Peer review remains a pillar of scholarly publication. It is perhaps the best example of a community-wide way to practice science and it should provide authors with important feedback in an aim to improve the work (Masuzzo & Martens, 2017). Historically, the selection of peers was organised by the academic societies charged with the editing and publishing. To avoid personal conflicts between researchers, this peer review was mostly performed anonymously. When publishers took over the business, this process remained the same and it has since been accused of inefficiency, and its fairness questioned for being generally permissive to abuses and partiality. A substantial number of articles have questioned the process and raised issues with the consistency of the review, its, ethics, cost, and the speed of the process (Berquist, 2012). In the current system of peer review, pre-publication reviews are discarded as soon as the articles are published as its main function seems to be helping editors decide which submitted papers to publish or, and a lot of the insight is discarded and opportunities for improvement wasted (Masuzzo & Martens, 2017).

The move towards transparency in this process consists in removing anonymity, thus making reviewers assume their responsibilities and possible conflicts of interest. Moreover, it allows for giving credit where credit is due – reviewing is a heavy task if handled with care and crediting reviewers' work motivates them even further to perform the task rigorously (Rentier, 2019).

Open Data. In the digital age, data is the foundation of many discoveries and can be found all fields of research, from material sciences to life sciences and humanities. Much as research results must be accessible, the underlying data should also be shared. The amount of research data produced is growing exponentially, but infrastructures, policies, and practices are still lacking to effectively exploit this resource, for data remains largely fragmented, isolated, and blocked by complex technical, legal, and financial restrictions. By removing those barriers, analysis of the wealth of data generated by research encourages more extensive and collaborative research, and innovation (Rentier, 2019).

Open Data is data freely available to the public, permitting any user to download, copy, analyse, re-process, pass them to software, or use them for any other purpose without any barriers, financial or legal. Borgman (2015) identified four rationales for sharing research data: to reproduce research, to make the data that can be considered public assets available to the public, to leverage investments in research, and to advance research and innovation.
The goal of Open Data is not simply to release data, it is to encourage its re-use. For that, data sharing needs to become a custom routine, encompass the full research cycle, and to ensure long-term preservation (Masuzzo & Martens, 2017). Researchers who plan to release their data will have more amount of work in the initial stages of research (McKiernan et al., 2016). As such evaluation and credit system must accommodate to acknowledge these practices. This work will further address the importance of pursuing Open Data practices for the transition to Open Science.

Open Code. Similar to data, the code which researchers use to analyse data is a vital part of the scientific research. Much like it, it is necessary to reproduce, interpret the results, and its corresponding conclusions, and answer novel research questions. For instance, if researchers use a software to obtain results from data, then this software should be released as well (Ince et al., 2012).
Open-source code refers to software that is made available under a license that permits anyone to use, change, improve, or derive from existing source code, and sometimes even to distribute the software. When a software is developed through open-source code, it allows other researchers to verify and contribute to its development, much like the principle of peer review, it allows for more transparency, better reliability, and also lower costs (Open Source Initiative, 2007). If a closed source software is used at any stage of

research, it does not allow for reproducibility of results and the principle of Open Science is not respected (Rentier, 2019).

4. Discussion

4.1. Benefits of Open Science

Open publications tend to achieve higher citation rates (Hitchcock, 2016; McKiernan et al., 2016). A study by Eysenbach (2006) analysing articles published in the journal 'Proceedings of the National Academy of Sciences' under their Open Access and non-Open Access options showed that open articles were twice as likely to be cited within 4 to 10 months and nearly three times likely in 10 to 16 months after publication. In the same year, findings by Hajjem et al. (2006) reached the same conclusion after analysing more than 1.3 million articles published in ten different disciplines over a twelve-year period. Open Access articles had a 36 to 172% advantage in citations over non-open articles. While one can argue there are controlled studies which failed to find a difference in citations between Open Access and non-open articles (e.g., Davis, 2011; Davis et al., 2008) many studies surely confirm this advantage. For instance, from the studies registered in the Scholarly Publishing and Academic Resources Coalition Europe (SPARC Europe) database of citation studies, 66% found an advantage to Open Access citation, 24% found no advantage and 10% were inconclusive (SPARC Europe, 2016). Of two of those studies, estimates of citation advantage range from -5% to 600%, in the case of Swan (2010), and 25% to 600% in the case of Wagner (2010). Figure 2 shows the size of the advantage in 19 fields of research (McKiernan et al., 2016).

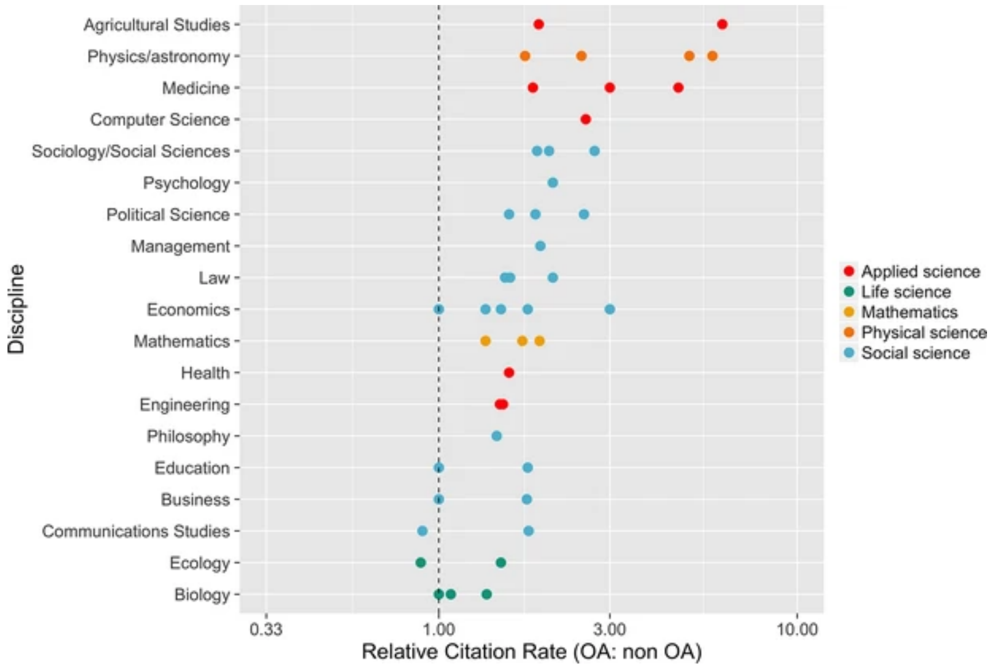

Figure 2. Graphic representation showing the relative citation rate in 19 fields of research. The rate is defined as the mean citation rate of Open Access articles divided by the mean citation rate of non-Open Access articles. Multiple points in the same field indicate either different estimates in the same study or estimates from several studies. Reprinted from "How Open Science helps researchers succeed" by McKiernan et al., 2016: p. 2. https://doi.org/10.7554/eLife.16800.002

Also, important to note is that citation advantage is observed whether articles are published in fully Open Access journals, subscription journals with Open Access options, often called hybrid journals, or self-archived in open repositories (McKiernan et al., 2016).

There is also evidence correlating citation rates to media coverage, showing news coverage confers citation advantage. Findings by Phillips et al. (1991) show that articles covered by the New York Times received up to 73% more citations. Adie (2010) studied over 2,000 articles published in *Nature Communications* and the attention they garnered on Twitter and found that open articles received nearly double the number of *tweets* than articles published in closed access. Accordingly, Wang et al. (2015) found that Open Access articles received 2.5 to 4.4 times the number of views and earned more attention via Facebook and Twitter.

Not only publishing openly but sharing research data also correlates with citation advantage. Several studies from multiple fields show the positive effects of data sharing: Piwowar and Vision (2013) analysed more than 10,000 studies on microbiology and found a 9% citation advantage for papers with shared data; Henneken and Accomazzi (2011), in the field of astronomy, showed a 20% increase in citations. Gleditsch et al. (2003) found the same effects in social sciences: articles published in the *Journal of Peace Research* offering data – either through appendices, URLs or contact addresses, were cited twice as much on average as articles without data offering. Open code practices also boost citation (McKiernan et al., 2016).

However, one must be careful to not make the same mistake of focusing only on citations to judge a paper's importance. As we have seen, citation-based methods may underestimate the scientific contribution of resource sharing in research because many of datasets and software packages shared are published under stand-alone outputs, meaning they are not associated with an article and cannot be cited. Therefore, we must look at other information to understand their importance in research. Pienta et al. (2010) analysed over 7,000 research projects and reported that projects with archived data produced an average of ten publications, double the number of publications without data sharing. To ensure data and software creators receive credit, research outputs – whether it is databases or software – must be traced, allowing for the researcher's work to be cited. Many Open

Data and software repositories have begun to assign Digital Object Identifiers (DOI) to these works (McKiernan et al., 2016). Researchers register their data or software under a unique Open Researcher and Contributor ID (ORCID) to track their contributions to other papers. Data and software sharing signals credibility and good research practices that can increase productivity in science and reduce errors and benefits researchers by promoting reuse, extension, and citation.

Another advantage of submitting articles and data to open repositories is that it ensures preservation and accessibility in the future, not just for other researchers but for the author as well, as it facilitates later reuse of the articles and data. Having access to the data, code, and materials makes the research easier to reproduce (Gorgolewski & Poldrack, 2016). Another benefit of Open Science arises from the findings by Wicherts (2016) that show data sharing correlates with fewer reporting errors when compared to papers with unavailable data. The same author says it facilitates collaboration with other peers by creating opportunities to interact and contribute to other projects. This collaborative mindset is best seen in the open-source software scientific community, where, in many scientific fields, data processing is hosted and developed openly, allowing anyone to contribute (McKiernan et al., 2016). For instance, in the field of machine learning, scikit-learn code package has attracted over 20,000 individual code contributions and 2,500 article citations (Pedregosa et al., 2011).

For researchers, there are other benefits to publish openly. For example, hardly a publisher agrees to publish negative results or failures, despite being imperative that they are known. For researchers, they often represent a considerable amount of effort that will not be considered when they are subjected to evaluation. Furthermore, publishing negative results is imperative for it prevents other researchers from pursuing the same dead-end hypothesis and wasting resources. Open Access allows for a disinterested publication and necessary interaction among researchers (Rentier, 2019).

To make their discoveries public, scientists usually forfeit the copyrights of their intellectual labour products to publishers. However, Open Access articles are generally published under Creative Commons (CC) licenses, under which authors retain copyright and grant specific, non-exclusive, reuse rights to publishers, as well as other users. Moreover, CC licenses require attribution which allows authors to receive credit for their work and accumulate citations. Copyright holders consenting to Open Access using a CC license are agreeing with unrestricted reading, downloading, sharing, printing, and linking to the full text of the work. Authors can choose the conditions in which their work is

handled. In essence, these conditions can prevent misrepresentation and enable legitimate scholarly use. Thus, it means lawful sharing and not an infringement of the law. Of course, Open Access can be poorly implemented that it infringes copyright, but so can traditional publishing (Suber, 2015). Through open licensing, researchers retain control over their works and how it is shared and used (McKiernan et al., 2016).
Harvard University and the Massachusetts Institute of Technology, for instance, adopted rights-retention Open Access policies prior to publication (Harvard University, 2016; MIT Libraries, 2016). These policies involve an agreement by the faculty to grant universities non-exclusive rights on future published works, meaning work produced in the faculties can be openly archived without the university negotiating with publishers to retain or recover rights – and so Open Access is the default.

There is no controlled study comparing peer review of Open Access journals and subscription ones, but the common belief that Open Access journals have poor peer-review appears to be unfounded (McKiernan et al., 2016). In fact, transparent models of peer review have been adopted by several Open Access journals like, for instance, PeerJ and the Royal Society of London's Open Science, which offer reviewers the option to publish the full peer review history alongside their articles. In 2014, PeerJ (2014) reported that about 80% of the authors chose precisely to publish reviewer reports alongside their articles. A transparent peer review process allows for a dialogue between the parties involved in the publication process, and some studies suggest it may help in producing better substantiated claims and constructive criticism (Kowalczuk et al., 2013; Walsh et al., 2000). Although the original intent of anonymity was praiseworthy, the traditional peer review process leaves much to be desired and opening the process would mean exciting perspectives (Rentier, 2019). McKiernan et al. (2016) state that the level of agreement between the author and reviewer was well below average. An open and transparent peer review can help address some of these issues and allow for positive discussion in the academy. Rentier (2019) believes it is only a matter of time until the myth of poor peer review in Open Access journals is dispelled, as researchers can read the reviews and confirm the process is as rigorous as of subscription journals – or even more since the reader can actually have the opportunity to attest the quality and even participate in the process, this is called a "liquid publication", when an article continues to evolve after its initial publication.

Nevertheless, there is a discouraging barrier to publishing articles in Open Access journals. Researchers often cite high costs in the form of Article Processing Charges (APC) associated with publishing in open journals. APCs are fees which the researcher pays in order to make their article, or other research output, Open Access (Lawson, 2015). Publishers which own Open Access journals, faced with the possibility of a reduction of subscription profits, have chosen to reverse the principle and started demanding payment for publishing, instead of reading. Using the abovementioned benefits associated with publishing openly, mainly the faster and wider dissemination, and building on their prestige, publishers convince researchers to publish openly on their journals. Furthermore, the price of APCs has also been rising. From 2010 to 2019, the average APC price increased 50%, a rate three times the inflation rate from this time frame (Morrison, 2020). Research funding organizations, governments and universities started to cover the payment of APCs, believing they are solving the problem (Lawson, 2015). In reality, these institutions are encouraging a system which harms low and middle-income countries that find it difficult to comprehensively cover these costs. This means that researchers from those countries are able to read the journals freely but largely unable to publish. However, one thing that must be noted is that the majority of open journals do not charge APCs. In 2020, 69% of those journals did not charge (Crawford, 2021). Likewise, 73% of the Open Access journals in the Directory of Open Access Journals did not charge APCs in 2019 (Morrison, 2020). From those that do charge, the global average is 908 USD (Morrison, 2019). Open Access journals charging higher publication fees often offer fee waivers upon request for authors with financial constraints and full or partial waivers for those in lower-income countries. Some charge a one-time membership fee that allows an author to publish one article per year, subject to peer review. That is the case of *PeerJ* with a membership fee of 199 USD. Importantly, most open journals do not charge additional fees for colour figures, which can sometimes sum to hundreds or thousands of dollars. Neuron, a journal by the publisher Elsevier, charges 1 000 USD for the first colour figure, and each additional one is 275 USD. Morrison (2020) compared APCs price by language and found that the tendency to charge varies significantly. Ninety-eight percent of the journals published in Portuguese, Spanish, and French do not have publication fees, while a third of the English-language journals charge APCs.

5. Concluding Remarks

The 20th century and the growth of resources allocated to scientific research attracted the attention of commercial publishers that formed huge multinational companies. Regarding the problems research finds in the current model of transmission of knowledge, this paper found that, today, scholarly publishing is in the hands of a few major publishers that enjoy ever growing profits and profit margins – higher than Google, Amazon, and Apple. Government's lack of regulatory practices to limit such commercial appropriation of scientific publishing is not acceptable for a sector with such a responsibility to society. The oligopolistic condition of the market led to an escalation of subscription prices, for which big publishers seem to not have reasonable justifications, that universities and libraries cannot keep up. Researchers supply their work, often without compensation, to commercial publishers, the State often funds the research and the researcher's salary, all to increase the profits of commercial publishers that in turn hugely impact universities' budgets. This system does not benefit anyone except for commercial publishers. The symbolic function of publishers is to allocate academic capital (recognition), for researchers are evaluated according to the journals they publish on. Since journals are evaluated using the impact factor, researchers are ultimately being evaluated by a metric which was not designed for that purpose. Like it is shown, the impact factor has many flaws and is being misused. Institutions should stop relying on the impact factor for their considerations and adopt responsible and integrative assessment methods. Harvard, the UK's Higher Education Funding Council, and other 2,000 more institutions have signed the DORA (2012) and stated their commitment to encourage and adopt Open practices in research assessment as a first step towards Open Science.

Many of the discussions about Open Science can be somewhat fearful for researchers - they are but victims of numerical evaluations and publisher's abuse, and a radical change can be frightening. As such, researchers need encouragement to explore other pathways and the associated benefits of Open Science. As researchers adopt open practices, share their work, and experience the benefits, they will likely become increasingly comfortable with sharing and willing to experiment with open practices. Acknowledging and supporting incremental steps in a positive environment is a way to respect researcher's present comfort and produce a gradual culture change. Training of researchers early in their careers is fundamental. As it is recommended by UNESCO (2017), Open Science practices, training on publishing practices, methods courses on proper citation, author rights, and information on open publishing options should be integrated in the regular curriculum, so as to not increase the time burden on students and researchers.

Even though the technological evolution necessary to enable Open Science has been available for almost two decades, progress has been slower than anticipated and there remains real obstacles to overcome. The European Commission notes that there is a disparity in progress among different disciplines and institutions, among different actors and organisations, and among researchers at different stages of their career. This is the result of a lack of policy alignment across Member-States, and of no clear legal or regulatory framework. The Commission also acknowledges that more cost/benefits analysis would propel Member-States to up their support for Open Science.

The collaborative characteristics of Open Science mean a democratization of knowledge. Not only Open Science serves to foster enhanced sharing of scientific knowledge, but it must also promote inclusion of scholarly knowledge from marginalized groups (such as women, minorities, indigenous scholars, non-Anglophone scholars, scholars from less-advantaged countries). In this way, it addresses existing systematic social inequalities, and enclosures of wealth, knowledge, and power, guiding scientific work towards including a more active participation of new social actors (UNESCO, 2020). The transformative potential of Open Science to change scientific process to a more respectful and inclusive of the diversity of cultures and knowledge systems is an opportunity to foster open and equitable dialogues between cultures. Open Science implies an intercultural pursuit as it relies on intercultural communication and collaboration and requires all the stakeholders to be interculturally competent.

The global COVID-19 health crisis has proven worldwide the urgency of access to scientific information, sharing of scientific knowledge and data, to enhance scientific collaboration and more informed science-based decision making by governments and institutions. This is particularly relevant not just for the current pandemic, but also for addressing future complex and interconnected environmental, social, and economic challenges. Open Science has a vital importance in responding to these issues by providing solutions to improve living standards, human well-being, tackle rising inequalities and disparities of opportunity around the world and foster sustainable social development.

6. References

Adie, E. (2014). Attention! A study of open access vs non-open access articles. *Figshare*. 10.6084/m9.figshare.121369

Adler, R., Ewing, J., & Taylor, P. (2008). Citation statistics. *Statistical Science*, *24*(1), 1-14.10.1214/09-sts285

Amin, M., & Mabe, M. (2000). Impact factors: use and abuse. *Perspectives in Publishing*. Retrieved from: https://rauterberg.employee.id.tue.nl/publications/amin-mabe-2000.pdf

Begley, C. G., & Ioannidis, J. P. (2015). Reproducibility in science: improving the standard for basic and preclinical research. *Circulation Research*, *116*(26). 10.1161/CIRCRESAHA.114.303819

Bergstrom, T. C. (2001). Free labor for costly journals? *Journal of Economic Perspectives*, *15*(4), 183-198. 10.1257/jep.15.4.183

Berquist, T. H. (2012). Peer review: Is the process broken? *American Journal of Roentgenology*, *199*(2), 243-243. 10.2214/ajr.12.9256

Björk, B., & Solomon, D. (2013). The publishing delay in scholarly peer reviewed journals. *Journal of Informetrics*, *7*(4), 914-923. 10.1016/j.joi.2013.09.001

Borgman, C. L. (2015). Big data, little data, no data. 10.7551/mitpress/9963.001.0001

Bosch, S., Albee, B., & Romaine, S. (2019). Deal or no deal | Periodicals price survey 2019. *Library Journal*.

Buranyi, S. (2017). Is the staggeringly profitable business of scientific publishing bad for science? *The Guardian*.

Crawford, W. (2021). *Gold open access journals, 2015-2020*. Cites & Insights Books.

Davis, P. M. (2011). *Open access, readership, citations: a randomized controlled trial of scientific journal publishing*. FASEB Journal, 25, 3229- 2134. 10.1096/fj.11-183988

Davis, P. M., Lewenstein, B. V., Simon, D. H., Booth, J. G., & Connolly, M. J. (2008). Open access publishing, article downloads, and citations: Randomised controlled trial. *BMJ*, *337*, a568. 10.1136/bmj.a568

Declaration on Research Assessment (DORA). (2012). San Francisco declaration on research assessment. Retrieved from: https://sfdora.org/read/

Eysenbach, G. (2006). Citation advantage of open access articles. *PLoS Biology*, *4*(157). 10.1371/journal.pbio.0040157

Garfield, E. (1955). Citation indexes for science: A new dimension in documentation through association of ideas. *Science*, *122*(3159), 108- 111. 10.1126/science.122.3159.108

Garfield, E. (1999). Journal impact factor: a brief review. *Canadian Medical Association Journal*, 161(8), 979-980.

Gleditsch, N. P., Metelits, C., & Strand, H. (2003). Posting your data: will you be scooped or will you be famous? *International Studies Perspectives*, *4*, 89-97.10.1111/1528-3577.04105

Gorgolewski, K. J., & Poldrack, R. A. (2016). A practical guide for improving transparency and reproducibility in neuroimaging research. *PLoS Biology*. 10.1101/039354

Hajjem, C., Harnad, S., & Gingras, Y. (2006). Ten-year cross-disciplinary comparison of the growth of open access and how it increases research citation impact. arXiv:cc/0606079

Harvard Library, Office for Scholarly Communication. (2016). Open Access policies. Harvard OSC. Retrieved from: https://osc.hul.harvard.edu/policies/

Henneken, E. A., & Accomazzi, A. (2011). *Linking to data-effect on citation rates in astronomy*. arXiv: 1111.3618

Hitchcock, S. (2016). The effect of open access and downloads ('hits') on citation impact: a bibliography of studies. Retrieved from: https://eprints.soton.ac.uk/354006

Ince, D. C., Hatton, L., & Graham-Cumming, J. (2012). The case for open computer programs. *Nature*, *482*(7386), 485-488.10.1038/nature10836

Khabsa, M., & Giles, C. L. (2014). The number of scholarly documents on the public web. *PLoS ONE*, *9*(5), e93949.10.1371/journal.pone.0093949

Kowalczuk, M. K., Dudbridge, F., Nanda, S., Harriman, S. L., & Moylan, E. C. (2013). *A comparison of the quality of reviewer reports from author-suggested reviewers and editor-suggested reviewers in journals operating on open or closed peer review models*.

Kumar, A. (2018). Is “Impact” the “Factor” that matters…? (Part I). *Journal of Indian Society of Periodontology*, *22*(2), 95.10.4103/jisp.jisp_195_18

Lancaster, A. (2016, June 28). *Open Science and its discontents*. Ronin Institute. Retrieved from: https://ronininstitute.org/open-science-and-its-discontents/1383

Larivière, V., Haustein, S., Mongeon, P. (2015). ‘The oligopoly of academic publishers in the Digital Era’. *PLOS ONE*, *10*(6) e0127502. 10.1371/journal.pone.0127502

Lawson, S. (2015). Article processing charges paid by 25 UK universities in 2014. *Journal of Open Humanities Data*, *1*. 10.5334/johd.2

Lyman, P., & Chodorow, S. (1998). 'The future of scholarly communication', in *The mirage of continuity: Reconfiguring academic information resources for the 21st century*, ed. B.L. Hawkins & P. Battin, Washington, D.C.

Masuzzo, P., & Martens, L. (2017). Do you speak Open Science? Resources and tips to learn the language. *PeerJ Preprints*, *5*(26891). 10.7287/peerj.preprints.2689v1

McKiernan, E., Bourne, P. E., Brown, C. T., Buck, S., Kenall, A.,…, K. H., & Yarkoni, T. (2016). Point of View: How Open Science helps researchers succeed. *eLife*, *5*(16800). 10.7554/eLife.16800

MIT Libraries, Scholarly Publishing. (2016). MIT faculty Open Access policy. https://libraries.mit.edu/scholarly/mit-open-access/

Morrison, H. (2020). *OA APC longitudinal survey 2019*. Sustaining the Knowledge Commons. Retrieved from: https://sustainingknowledgecommons.org/2019/11/27/oa-apc-longitudinal-survey-2019/

Morrison, H., & Singh, S. (2019, December 9). *OA journals non-charging and charging central trends 2010 – 2019*. Sustaining the Knowledge Commons / Soutenir les savoirs communs. Retrieved from: https://sustainingknowledgecommons.org/2019/11/23/oa-journals-non-charging-and-charging-central-trends-2010-2019/

Office of Fair Trading. (2002). The market for scientific, technical and medical journals (OFT396). Retrieved from: http://econ.ucsb.edu/~tedb/Journals/oft396.pdf

Open Source Initiative. (2007). Retrieved from: https://opensource.org/docs/osd

Pedregosa, F., Varoquaux, G., Gramfort, A., Michael, V., Thirion, B.,…, & Duchesnay, E. (2011). 117 Scikit-learn: machine learning in python. Journal of Machine Learning Research, 12, 2825-2830.

PeerJ Staff. (2014, October 21). Who's afraid of Open Peer Review? PeerJ. Retrieved from: https://peerj.com/blog/post/100580518238/whos-afraid-of-open-peer review

Phillips, D. P., Kanter, E. J., Bednarczyk, B., & Tastad, P. L. (1991). Importance of the lay press in the transmission of medical knowledge to the scientific community. *New England Journal of Medicine*, *325*, 1180- 1183. 10.1056/NEJM199110173251620

Pienta, A. M., Alter, G. C., & Lyle, J. A. (2010). The enduring value of social science research: the use and reuse of primary research data. Retrieved from: https://deepblue.lib.umich.edu/handle/2027.42/78307

Piwowar, H., & Vision, T. J. (2013). Data reuse and the open data citation advantage. PeerJ, 1(175).10.7717/peerj.175

Rentier, B. (2019). *Open Science, the challenge of transparency*, Académie royale de Belgique, Brussels. Retrieved from: https://orbi.uliege.be/bitstream/2268/233905/1/Open%20Science%20En%20%28Author%29.pdf

Rentier, B. (2015). Denouncing the impact impostor. Retrieved from: https://bernardrentier.wordpress.com/2015/12/31/denouncing-the-imposter-factor/

Saha, S., Saint, S., & Christakis, D. (2003). Impact factor: a valid measure of journal quality? *Journal of the Medical Library Association*, *91*(1), 42- 46.

Seglen, P. O. (1997). Why the impact factor of journals should not be used for evaluating research. *BMJ*, *314*(7079), 497- 497.10.1136/bmj.314.7079.497

Schmitt, J. (2015). Academic journals: The most profitable obsolete technology in history. Retrieved from: *HuffPost*. https://www.huffpost.com/entry/academic-journals-the-mos_1_b_6368204?guccounter=1

SPARC Europe. (2016). *The open access citation advantage service*. Retrieved from: http://sparceurope.org/oacal/

Suber, P. (2015). *Open Access overview*. Earlham College. Retrieved from: https://legacy.earlham.edu/~peters/fos/overview.htm

Swan, A. (2010). The open access citation advantage: studies and results to date. Retrieved from: https://eprints.soton.ac.uk/268516/

Tenopir, C., & King, D. W. (1997). Trends in scientific scholarly journal publishing in the United States. *Journal of Scholarly Publishing*, *28*(3), 135-170. 10.3138/jsp-028-03-135

UNESCO. (2017). Recommendation on science and scientific researchers (39 C). Retrieved from: https://unesdoc.unesco.org/ark:/48223/pf0000260889.page=116

UNESCO. (2020). First draft of the UNESCO Recommendation on Open Science. Retrieved from: https://unesdoc.unesco.org/ark:/48223/pf0000374409.page

Wagner, A. B. (2010). Open access citation advantage: an annotated bibliography. *Issues in Science and Technology Librarianship*, *60*.10.5062/F4Q81B0W

Walsh, E., Rooney, M., Appleby, L., & Wilikinson, G. (2000). Open peer review: a randomised controlled trial. *British Journal of Psychiatry*, *176*, 47- 51. 10.1192/bjp.176.1.47

Wang, X., Liu, C., Mao, W., & Fang, Z. (2015). The open access advantage considering citation, article usage and social media attention. *Scientometrics*, *103*(2), 555-564. 10.1007/s11192-015- 1547-0

Watson, M. (2015). When will "Open Science" become simply "science"? *Genome Biology*, *16*(101).

Wilsdon, J., Allen, L., Belfiore, E., Campbell, P., Curry, S.,…, & Johnson, B. (2016). The metric tide: Independent review of the role of metrics in research assessment and management. SAGE.10.13140/RG.2.1.4929.1363

Wicherts, J. M. (2016). Peer review quality and transparency of the peer-review process in open access and subscription journals. *PLoS ONE*, *11*(1), e0147913. 10.1371/journal.pone.0147913