A Billion Dollar Donation:

The Cost, and Inefficiency of, Researchers' Time Spent on Peer Review

Balazs Aczel[a*], Barnabas Szaszi[a*],

Alex O. Holcombe[b]

[a]*Institute of Psychology, ELTE, Eotvos Lorand University, Budapest, Hungary*

[b]*School of Psychology, University of Sydney, Sydney, Australia*

Keywords: peer-review, academic publishers, publication system

Authors for correspondence: balazs.aczel@gmail.com

*Present address: Institute of Psychology, ELTE, Eotvos Lorand University, Izabella u. 46, 1064, Budapest, Hungary

Abstract

Background

The amount and value of researchers' peer review work is critical for academia and publishing. However, it is rarely recognized, its magnitude is unknown, and alternative ways of organizing peer review labor are rarely considered.

Methods

In this paper, we provide an estimate of researchers' time and the salary-based contribution to the peer-review system, using publicly available data.

Results

We found that the total time reviewers globally worked on peer reviews was over 100 million hours in 2019, equivalent to over 12 thousand years. The estimated monetary value of the time US-based reviewers spent on reviews was over 1.1 billion USD in 2019. For China-based reviewers, the estimate is over 600 million USD, and for UK-based, over 200 million USD.

Conclusions

While these results are only rough estimates, they highlight the enormous amount of work and time that researchers provide to the publication system, and the importance of considering alternative ways of structuring, and paying for, peer review. We foster this process by discussing some alternative models that aim to improve the return on investment of scholarly publishing.

Background

The main product of the academic publication system, the journal article, is a co-production of scientists and publishers. Scientists provide value not only by doing the research and writing up the results as a manuscript, but also by serving as peer reviewers. Although several careful estimates are available regarding the cost of academic publishing (e.g., 1), one aspect these estimates often neglect is the cost of peer reviews. Therefore, one aim was to provide a timely estimation of reviewers' contribution to the publication system in terms of time and financial value.

In their peer reviewer role, researchers provide comments to help improve other researchers' manuscripts and judge their quality. They offer their time and highly specialized knowledge to provide a detailed evaluation and suggestions for improvement of manuscripts. A manuscript typically receives multiple rounds of reviews before acceptance, and each round typically involves two or more scientists as peer reviewers. In science, peer review work is rarely formally recognized or directly financially compensated within this system (an exception are book reviews in humanities, which sometimes are financially compensated). Most universities seem to expect their academics to do review work as part of their research or scholarly service mission, although we know of none with an explicit policy about how much time they should spend on it. Although the amount and value of peer review work is a critical element of academic publishing, their magnitude is presently unknown. A previous estimate put the global non-cash cost of researchers' peer-review activities for 2007 to £ 1.9bn (2).

Recently, the fairness and efficiency of the traditional peer review system became a heated topic among academics (3–5). In this paper, we provide an update on the estimate of researchers' time and the salary-based contribution to the peer-review system. We used publicly available data for our calculations following estimation methods customary in this area of research. We discuss the implications of our estimates and identify a number of alternative

models for better utilizing research time in peer-review.

Methods and Results

To estimate the time and the salary-based monetary value of the peer review conducted for journals in a single year, we had to estimate the number of peer-reviews per year, the average time spent on a review, and the hourly labor cost of academics. In case of uncertainty, we used conservative estimates for our parameters, therefore, the true values are likely to be above our results.

Number of peer-reviews per year

Only estimates exist for how many reviews associated with journals occur each year. Publons (6) estimated that the 2.9 million articles indexed in the Web of Science in 2016 required 13.7 million reviews. To calculate the number of reviews relevant to 2019, we used the formula used by Publons (6) - equation 1 below. In that formula, a review is what *one* researcher does in *one* round of a review process. For submissions that are ultimately accepted by the journal submitted to, the Publons formula assumes that on average there are two reviews in the first round and one in the second round; for rejected articles (excluding desk-rejections) the formula assumes an average of two reviews for submissions that are ultimately rejected, both in the first round.

Publons estimated the acceptance rate for peer-reviewed submissions to be 55%. That is, 45% of manuscripts that are not desk rejected are, after one or more rounds of review, ultimately rejected. Before including Publons' assumptions in our calculations, we evaluated them based on the records available. Mean acceptance rates have apparently declined during this century - according to Thomson Reuters, for example (7), the proportion of submissions that are eventually accepted by a journal was 0.40 in 2005: 0.37 in 2010, and 0.35 in 2011 (8,9).

We did not find estimates of acceptance rates for the last several years, but we assume

that the decline described by Reuters (7) continued to some extent, and assume that the present mean acceptance rate at journals is 0.30 then we can arrive at Publons' figures. However, for the final numbers, we also need to estimate the rate of desk rejections as well. Published values (10,11) and journal publisher estimates[1] lead us to estimate this value around 0.45.

The above estimates imply that, on average, every 100 submissions to a journal or refereed conference proceeding, comprise 30 that are accepted after one or more rounds of peer review, 45 that are desk rejected, and 25 that are rejected after review. Thus, among submissions sent out for review, 55% (30 / (30 + 25)) are ultimately accepted. That is, the articles published represent 55% of all reviewed submissions, indicating that 45% of submissions that were reviewed were rejected. These values are undoubtedly speculative, but they are consistent with Publons' estimations. Therefore, to estimate the number of peer reviews per year, we used Publons' formula:

$$Nr\ of\ submissions_{accepted} \times Average\ Nr\ of\ reviews_{accepted} + Nr\ of\ submissions_{rejected} \times Average\ Nr\ of\ reviews_{rejected}$$

Equation 1, based on Publons (6)

To obtain these values, we had to estimate the number of peer reviews performed for articles in 2019. For that, we used the publicly available numbers reported by the Scimago Journal & Country Rank portal (www.scimagojr.com) based on the Scopus journal database. Their data table includes both peer-reviewed articles and peer-reviewed conference papers, without providing separate figures for the two, so henceforth we will use the term "article" to refer to both. When an article has multiple authors from different countries, when country-specific numbers are required (see below), the numbers in the Scimago database are based on

[1] https://www.elsevier.com/authors-update/story/publishing-tips/5-ways-you-can-ensure-your-manuscript-avoids-the-desk-reject-pile

proportional and fractional assignments to each country.

The total number of articles published in 2019 according to the Scimago database is 3,900,066. Assuming that this sum reflects the 55% acceptance rate, the number of reviewed but rejected submissions (the 45% of all submissions) are estimated to be globally 3,900,066/55*45 = 3,190,963. Based on these calculations, the total number of reviews for articles published in 2019 is 3,900,066*3 + 3,190,963*2 = 18,082,124 (based on *Equation 1*).

Note that this number is an underestimate as Scimago does not index all published articles. For example, some journals (~10%) indexed in the Web of Science do not appear in Scimago (12).

Time spent on reviews

Several estimates exist for the average time a reviewer spends when reviewing a manuscript. A 2009 survey sent to 3,597 reviewers indicated that the reported median time spent on the last review was 6 hours (13). A similar survey in 2008 found that the average time spent with reviewing was 9 hours (14). To be conservative (and keeping in mind the tendency of people to overestimate how much time they work), we will use 6 hours as the average time reviewers spend on each review.

Based on our estimate of the number of reviews (11,700,198) and hours spent on a review (6), we estimate that in 2019 reviewers spent 18,082,124×6 hours = 108,492,744 hours on reviewing. This is equivalent to 12,385 years (at 365 days a year and 24 hours of labor per day) (Figure 1).

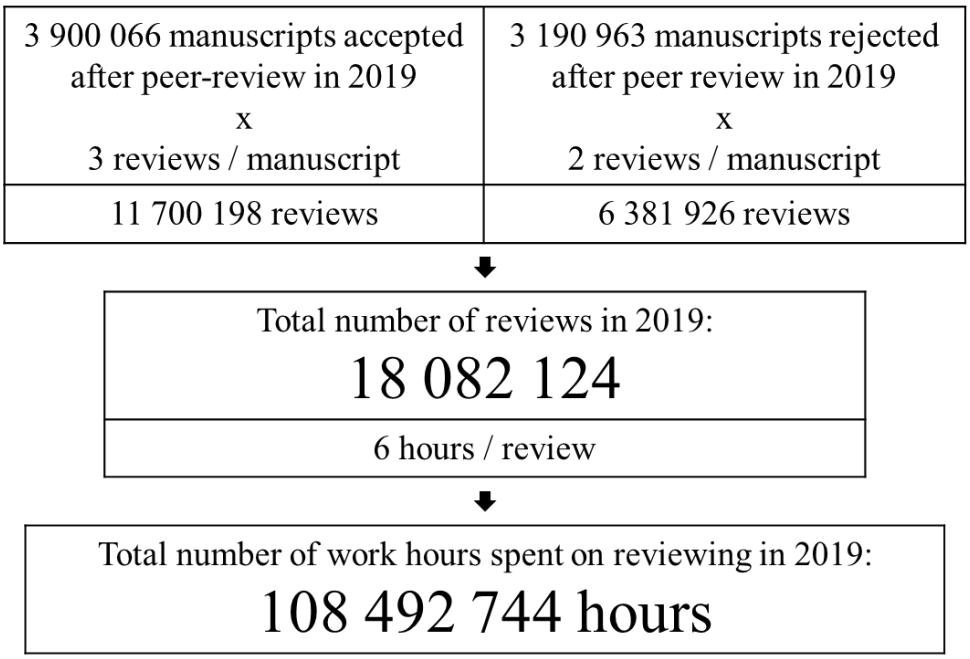

Figure 1. Overview of the calculation of time spent on reviewing for scholarly articles in 2019.

Hourly wage of reviewers

To estimate the monetary value of the time reviewers spend on reviews, we multiplied reviewers' average hourly wage by the time they spend reviewing. No data seem to have been reported about the wages of journal reviewers, therefore, we require some further assumptions. We assumed that the distribution of the origin of the reviewers is similar to the distribution of the authors. Countries that produce more articles are more involved in the review system, while countries with little scientific contribution take a proportionally smaller part in reviewing. Given the English-language and geographically Anglophone-centered concentration of scientific journals, we suspect that people in English-speaking countries are called on as reviewers perhaps even more than is their proportion as authors. Because such countries have higher wages than most others, our assumption of reviewer countries being proportional to author countries is conservative for total cost.

Based on the results of the Peer Review Survey (13), we assumed that reviewing is conducted almost entirely by people employed by academic workplaces such as universities and research institutes and that junior and senior researchers participate in reviewing in a ratio of 1:1. Therefore, to calculate the hourly reviewer wage in a given country we used *Equation 2*:

$$\frac{average\ annual\ post-doc\ salary\ +\ average\ annual\ full\ professor\ salary}{2\ \times\ annual\ labor\ hours}$$

This yields a figure of $68.78 per hour for the U.S., $50.85 for the UK, and $35.66 for China (Table 1).

Public spending on reviewing time

We estimated the value of reviewing by multiplying the calculated hourly reviewer wage in a country by the number of estimated reviews in that country and the time preparing one review. This yields, for the three countries that produced the most articles in 2019, over $USD1.1 billion for the U.S., $665 million for China, and $266 million for the UK (Table 1).

Table 1
Estimating the Value of Reviewing Time for the USA, China, and the UK for 2019

Parameter	**USA**	**China**	**UK**
Annual postdoc salary	$65 000	$37 854	$39 692
Annual full professor salary	$179 736	$117 207	$116 731
Annual labor hours	1 779	2 174	1 538
Reviewer hourly wage	$68.78	$35.66	$50.85
Articles	605 796	669 877	188 259
Rejections	495 651	548 081	154 030
Reviews	2 808 690	3 105 793	872 837
Value of reviewing time	$1 159 169 571	$664 562 006	$266 316 926

Note. Salary values were collected on 2020.09.09. from http://www.salaryexplorer.com/ for China and from https://inomics.com/sites/default/files/2018-05/INOMICS%20Salary%20Report%202018.pdf for the USA and

the UK. To convert the average Chinese salary to USD, we used the 2019 average exchange rates from CNY to USD based on https://www.macrotrends.net/2575/us-dollar-yuan-exchange-rate-historical-chart. For China, labor hours were found in https://ourworldindata.org/working-hours; for the USA and the UK they were retrieved from https://stats.oecd.org/Index.aspx?DataSetCode=ANHRS. The numbers of articles published in 2019 for each country are from https://www.scimagojr.com/countryrank.php?year=2019. For the calculation of the value of reviewing time, we used the non-rounded form of the reviewers hourly wages.

Discussion

The high price of scientific publishing receives a lot of attention, but the focus is usually on journal subscription fees, article processing charges, and associated publisher costs, such as typsetting, indexing, and manuscript tracking systems (e.g., 1). The cost of peer review is typically not included. Here, we found that the total time reviewers worked on peer reviews was over 100 million hours in 2019, equivalent to over 12 thousand years. The estimated monetary value of the time US-based reviewers spent on reviews was over 1.1 billion USD in 2019. For China-based reviewers, the estimate is over 600 million USD, and for UK-based, over 200 million USD. These are only rough estimates but they help our understanding of the enormous amount of work and time that researchers provide to the publication system while being paid by their universities and institutes.

Without major reforms, it is unlikely that reviewing will become more efficient, relative to other costs in publishing. One reason is that while automation is gradually contributing more to some aspects of publishing, thanks to improvements in technology, peer-review cannot be automated as easily.

A second issue is that while there is an ongoing effort to reduce publishing costs, this effort has not been directed at peer review, even though it is one of the costliest components of the system. Specifically, after a long period of above-inflation subscription journal price increases, funders have attempted to put downward pressure on prices through initiatives such as *PlanS* (15) and creating their own publishing infrastructure (e.g., Wellcome Open Research and Gates Open Research 16,17). However, because publisher prices do not include the cost of

peer review, putting pressure on them will likely have no effect on review labor costs. Peer review labor sticks out as a large cost that is not being addressed systematically by publishers or research funders.

In the remainder of this Discussion, we will review some innovations around peer review that have the potential to either reduce its cost or to make it more efficient. By more efficient, we mean an increase in the return on the investment in peer review labor that funders currently make. If the return on peer review labor could be boosted, then some of the funds presently used to pay for peer review labor might be used to support other goals, such as investments in software infrastructure to make other aspects of publishing more efficient, or greater independence from corporate publisher ownership.

We see at least three ways to boost the return on peer review labor. One is to decrease the amount of labor needed per published article by reducing redundancy in reviews. A second way is by better allocation of review labor. A third way is by unlocking the value of peer reviews, in part making them publicly available.

Reducing redundancy in peer review

An obvious source of inefficiency is that many manuscripts get reviewed at multiple journals. While improvements in the manuscript between submissions in some cases means that the reviewing process is not entirely redundant, typically at least some of the assessment being done is duplication. Based on survey data (18), we conservatively estimated that, on average, a manuscript is submitted to two journals before acceptance (including the accepting journal). In other words, each accepted article has a rejection and resubmission behind it. Should the reviews of a previous submission be always available to the journal of the new submission, reviewing time could be substantially reduced. Currently, around 70M reviewing hours are behind the accepted articles per year. Let's assume that the "passed on" or open

reviews would reduce the requirements by one review per manuscript. In this system, approx. 23M hours could be saved yearly. Just in the USA, it would mean saving work worth approx. 250M USD.

Some savings of this kind have already begun. Several publishers or journals now share reviews across journals (PLOS, Nature: ,19). Some also publish the reviews openly (PLOS; eLife; Meta-psychology), although typically not when the manuscript is rejected (Meta-psychology is one exception, and eLife will publish the reviews after a rejected manuscript is accepted somewhere else).

Improving the allocation of review labor

Matching

Today, most reviewers are matched to a manuscript with a process that is itself labor-intensive. For this matching process, the labor is done by an editor. We did not include editors' labor in our peer review calculations, and we know of no estimates of their work. Editors typically use a combination of their personal networks (their personal knowledge or opinions of who would serve as a good reviewer), any recommendations provided by the authors, the reference list of the manuscript, and a literature search. When things go well, the result of that process is the identification of experts capable of providing a review. Unfortunately, however, it is often the case that those experts are not interested in reading and reviewing that particular manuscript. Another problem is that they may be unavailable or too busy.

When a candidate reviewer does accept, they often do so out of a sense of obligation to the field, or to maintain a good relationship with the editor, rather than because it would benefit their ongoing scholarship to do so. Yet in the case of many manuscripts, there are multiple researchers around the world for whom reviewing the work would benefit their individual scholarship and who also are available at that time to do the work. By benefit to individual

scholarship, we are thinking of exports who are hoping to keep abreast of a particular topic, or those with relevant expertise but who want to learn more about a specific topic or technique. If more of such people can be matched with a manuscript, reviewing becomes more of a "win-win", with greater benefits accruing to the reviewer than is typical in the current system. Better matching, then, would mean an increased return on the portion of an employer's payment of a scientist's salary that pays for peer review.

Because some scholars who would be highly motivated to review a particular manuscript have no way of knowing what manuscripts have been submitted to a journal and need review, they cannot indicate their interest and availability. Conducting peer review in the open rather than in walled journal management systems can address this. The journal *Meta-psychology* and the online platform *PREreview* are examples of initiatives from the last decade that solicit reviews openly on the web rather than relying on individual emails by an editor to a small set of candidates. We should add, however, that peer review could or should always be done entirely by the most interested people, as high interest or motivation may be correlated with biases. An ideal peer review process should also take care to include someone who is somewhat disinterested that can provide a more neutral perspective.

Broadening and deepening the reviewer pool

Another unfortunate aspect of the allocation of review labor is that it typically tries to tap only the most highly-trained experts in a topic. That is, editors tend to look for world experts on a topic, often senior people whose labor is particularly costly, in addition to being in short supply and in high demand.

It is not clear that those who are highly expert in a field should be the only ones contributing to peer review. Evaluating a manuscript means examining multiple dimensions of manuscript. For some research areas, detailed checklists have been developed regarding all the

information that should be reported in a manuscript. This provides a way to divide up the labor and have some aspects where even students, after some training, can vet aspects of a manuscript. Thus we are hopeful that after more meta-research on what is desired from peer review for particular research areas, parts of peer review can be done by people who are not experts in the very specific topic of a manuscript but can nonetheless be very capable at evaluating particular aspects of a manuscript.

This process could also lead to greater specialization in peer review. For example, for manuscripts that report clinical trials, some people could be trained in evaluating the blinding protocol and success of blinding, and if they had the opportunity to evaluate that particular portion of many manuscripts, they grow better at it while simultaneously coming to do it more quickly.

In a small way, this specialization in peer review has already begun. As reporting standards for particular kinds of research have become more widespread (e.g., CONSORT for clinical trials, ARRIVE for animal research, and PRIMA for systematic reviews of randomized trials[2]), professional staff at some publishers have begun performing some checks for compliance with these standards. For example, staff at *PLOS* check all manuscripts on human subject research for a statement regarding compliance with the Declaration of Helsinki, and clinical trials research for a CONSORT statement. These staff presumably can do this job more efficiently, and do so for a lower salary, than an academic charged with peer reviewing every word of an entire manuscript.

Unlocking the value of reviews

A third way to boost the productivity of review labor is to unlock the value of the reviews. Peer reviews are scholarly outputs that include valuable information that contributes

[2] For their collection, see https://www.equator-network.org/.

to the production of knowledge. Under the currently-dominant system of closed peer review, however, only the authors, other reviewers, and editor of the manuscript have the opportunity to benefit from the content of the review.

When reviews are published openly, the expert judgments and information within reviews can benefit others. One benefit is the judgments and comments made regarding the manuscript. Reviews often provide reasons for caution about certain interpretations, connections to other literature, points about the weaknesses of the study design, and what the study means from their particular perspective. While those comments influence the revision of the manuscript, often they either don't come through as discrete points or the revisions are made to avoid difficult issues, so that they don't need to be mentioned.

It is not uncommon for some of the points made in a review to also be applicable to other manuscripts. Some topics of research have common misconceptions that lead to certain mistakes or unfortunate choices in study design. Some of the experienced researchers that are typically called upon to do peer review can rapidly detect these issues, and pass on the "tips and tricks" that make for a rigorous study of a particular topic or that uses a particular technique. But because peer reviews are traditionally available only to the editor and authors of the reviewed study, this dissemination of knowledge happens only very slowly, much like the traditional apprenticeship system required for professions before the invention of the printing press. How much more productive would the scientific enterprise be if the information in peer reviews were unlocked? We should soon be able to get a better sense of this, as this is already being done by the journals that have begun publishing at least some of their peer reviews (e.g, *Meta-psychology, eLife, the PLOS journals; F1000Research, Royal Society Open Science, Annals of Anatomy, Nature Communications, PeerJ* (20)). It will be very difficult, however, to put a financial value on the benefits. Fortunately, there are also other reasons that

suggest that such policies should be adopted, such as providing more information about the quality of published papers.

A limitation of the present study is that it does not quantify academic editors' labor, which is typically funded in part by universities and is integral to the peer review process. At prestige journals with high rejection rates, a substantial proportion of editors' time is spent desk-rejecting articles, which is wasteful, especially because many or most rejected articles are eventually published somewhere else.

A manuscript that one of us is an author on was submitted to six journals in the last two years before being accepted by the seventh we submitted it to. Only the seventh journal sent out the manuscript for external review, but one of the journals claimed that two editors (both academics) read the paper before deciding it should be desk-rejected, a second stated that at least one senior editor and a reviewing editor (both academics) assessed the manuscript, and a third journal stated that more than one professional (non-academic) editor read the manuscript. The six rejections amount to a very substantial amount of work on the part of the journal editors, as well as on the authors' part, because of the need to reformat the manuscript somewhat for each journal (18) and navigate the separate online submission systems.

Like many researchers do, for the manuscript referred to above, we started by submitting near the top of the impact factor hierarchy for our discipline. Based on the high rejection rates of such journals, such as >80% for multiple *Nature* journals (21) and for American Psychological Association journals such as *Journal of Educational Psychology*, *Journal of Experimental Psychology: General*, *Psychological Bulletin*, and *Journal of Personality and Social Psychology*[3], a substantial portion of their work hours may be spent on

[3] Summary Report of Journal Operations, 2019 and Summary Report of Division Journal Operations. https://www.apa.org/pubs/journals/statistics

rejecting and desk-rejecting manuscripts. Many manuscripts can be desk-rejected based on a very quick evaluation, but others take more of the editor's time.

Returning to the issue of non-editor peer review labor, the main limitations of this paper come from the limitations of the available data. For example, the Scopus database does not include all published articles, around 10% of the journals indexed in the Web of Science do not appear in Scimago (12) and unfortunately there is no available public database with all the scientific journals and published articles. Many journals do not provide yearly statistics on their peer review activities, so the rates of acceptance and rejections we used are approximate estimates. We could not calculate the cost of review for journal articles and conference papers separately, although they might differ in this regard. The nationality and salary of the reviewers are not published either, therefore, our calculations need to be treated with caution as they had to rely on broad assumptions. Nevertheless, the aim of this study was to estimate only the magnitude of the cost of peer review without the ambition to arrive at precise figures.

Conclusions

Funders have concentrated on making research open access, which helps to unlock the economic value of research, but have not focused on reducing cost. The constant improvements in technology have the potential to decrease the costs associated with most facets of the publishing process, but peer review continues to rely almost completely on human labor, and very highly-trained labor at that. Unless the efficiency of peer review is improved, then, science faces a cost disease situation. "Cost disease" (22) refers to the fact that while many products and services have steadily decreased over the last two hundred years, those that have remained very labor-intensive have not. This is the fate of scholarly publication, unless something is done to make peer review more efficient.

Ethics approval and consent to participate

This study had no data collection from participants.

Consent for publication

All authors approved the submission of the manuscript.

Availability of data and materials

The public dataset supporting the conclusions of this article is available from the www.scimagojr.com website.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was not funded.

Authors' Contributions

Conceptualization: BA and BS. Formal Analysis: BA and BS. Methodology: BA and BS. Writing - Original Draft Preparation: BA, BS, and AOH.

Acknowledgements

We are thankful to James Heathers for providing valuable feedback on an earlier version of the manuscript.

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