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Gold Open Access Publishing in Mega-Journals

DEVELOPING COUNTRIES PAY THE PRICE OF WESTERN PREMIUM ACADEMIC OUTPUT

JACINTHA ELLERS, THOMAS W. CROWTHER, and JEFFREY A. HARVEY

Open access publishing (OAP) makes research output freely available, and several national governments have now made OAP mandatory for all publicly funded research. Gold OAP is a common form of OAP where the author pays an article processing charge (APC) to make the article freely available to readers. However, gold OAP is a cause for concern because it drives a redistribution of valuable research money to support open access papers in 'mega-journals' with more permissive acceptance criteria. We present a data-driven evaluation of the financial ramifications of gold OAP and provide evidence that gold OAP in mega-journals is biased toward Western industrialized countries. From 2011 to 2015, the period of our data collection, countries with developing economies had a disproportionately greater share of articles published in the lower-tier mega-journals and thus paid article APCs that cross-subsidize publications in the top-tier journals of the same publisher. Conversely, scientists from Western developed countries had a disproportionately greater share of articles published in those same top-tier journals. The global inequity of the cross-subsidizing APC model was demonstrated across five different mega-journals, showing that the issue is a common problem. We need to develop stringent and fair criteria that address the global financial implications of OAP, as publication fees should reflect the real cost of publishing and be transparent for authors.

Keywords: article processing charge, financial transparency, gold open access, mega-journals, socio-economic status

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INTRODUCTION

Open access publishing (OAP) makes research output freely available on the Internet for anyone, without having to go through a paywall, and has caused a transformation of the scientific landscape. The benefits of OAP, which include the open availability of information free of charge and a faster dissemination of knowledge, have made open access a growing movement with strong support from academics and policy makers alike. One of the main reasons behind the momentum of the open access movement is that OAP offers a viable option to curb the exorbitant profits of some academic publishers by providing an affordable alternative to the rising subscription prices of paywall scholarly journals. Another impetus for the open access movement is a desire to improve public accessibility to scientific research.

Several national governments are considering policies to make OAP mandatory for all publicly funded research, and many funding agencies are under growing pressure to provide additional financial support to researchers to cover costs associated with certain forms of OAP. Recently European Union ministers of science declared that all publications should be open access by 2020.[1] These initiatives are intended to accelerate the transition from traditional closed publication systems to openly accessible ones. However, the benefits of OAP come with inherent pitfalls that must be considered and managed if society is to benefit from this new approach to scholarly publishing. A primary area of concern is gold OAP and its implications, in particular the associated increase in the number of publications and the lack of policy for financing them.

In recent years it has become clear that gold OAP, which is an author-pays business model, can be an economically profitable enterprise. In the author-pays system, publishers collect their revenue by charging a publication fee (an article processing charge, or APC) to authors when their manuscript is accepted and subsequently publish their article on the Internet at no cost to readers.

The so-called mega-journals[2] exploit the financial possibilities of the author-pays model to the fullest by making two strategic choices. First, these journals often have a reduced peer-review process,[3] which lowers the costs of manuscript handling. For instance, some mega-journals function as cascade journals, which publish manuscripts transferred to them from other journals of the same publisher that initially rejected

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the manuscripts. In this procedure the reviews are transferred as well, resulting in negligible extra costs for the publishers. Second, mega-journals usually have more permissive acceptance criteria, thereby increasing not only the number of papers they publish but also the proportion of handled manuscripts that eventually yield a publication fee. Effectively, rejection of manuscripts is a cost factor for an open access journal with the author-pays system because rejected manuscripts need to be handled but do not generate income. This is one of the reasons why highly selective journals rarely adopt OAP, as their stringent acceptance rates would render OAP unprofitable.[4] Consequently, gold OAP instates a positive relationship between high acceptance rates and economic profitability, and this leads to the redistribution of valuable research money to support open access papers in mega-journals with more permissive acceptance criteria.[5]

A successful illustration of this is the Public Library of Science (PLOS), a non-profit publisher with a suite of author-pays open access journals that have different stringencies of acceptance criteria. In 2015 PLOS generated more than $42 million of revenue from publication fees, the majority from *PLOS ONE*, a mega-journal that publishes over 31,000 papers annually (with an average Impact Factor [IF] from 2011 to 2015 of 3.5). As a publisher, PLOS relies on the cash flow from *PLOS ONE* to cross-subsidize its premium journals *PLOS Biology* and *PLOS Medicine* (IF 2011–2015 of 10.8 and 14.7, respectively).[6] Although publication fees are higher for these top-end journals, they are insufficient to cover the costs of these highly selective journals, which publish fewer than 10 per cent of submissions.[7] This is a rate of rejection similar to *Nature* and *Science* and dissimilar to the much higher acceptance rate of 69 per cent of *PLOS ONE*.[8] Many commercial publishers exploit similar sets of tandem journals, often with paywall premium journals and open access mega-journals, for example, *Scientific Reports* for Nature Publishing Group,[9] *Science Advances* for AAAS (publisher of *Science*), and *Ecology and Evolution* for Wiley Publishers. It has been argued that scientists publishing in these journals are overcharged[10] and that the publication fees paid are channeled toward the costs of publication of other research or to the profit of the publisher.

Whereas scientists are increasingly concerned about the high costs of publication fees,[11] thus far little attention has been given to the global consequences of mega-journals' profitable business model. For this study

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we compiled data on the number of publications, by country, in open access mega-journals and compared these counts to publications from the same countries in the premium journals of the same publishers. We present evidence that the financial burden of these costs of OAP is distributed unequally across developing and industrialized Western countries.

METHODS

We first identified five tandem sets, each consisting of an open access mega-journal and the premium journal(s) it supports (Table 1), by using information provided on the websites of the journals. We then selected five countries with developing economies and five industrialized Western countries for our analysis following the binary grouping of the United Nations Framework Convention on Climate Change. This convention recognized two groups of countries based on membership in the Organisation for Economic Co-operation and Development (OECD) in 1992:

TABLE 1. Tandem sets of mega-journal and premium journal(s) of five publishers, and the associated publication fees

Publisher	Mega-journal	Publication fee	Premium journal(s)	Publication fee
PLOS	*PLOS ONE*	$1495	*PLOS Biology*	$2900
			PLOS Medicine	$2900
Nature Publishing Group	*Scientific Reports*	$1495	*Nature*	None
Wiley	*Ecology and Evolution*	$1950*	*Divers Distrib, Ecol Lett, Evolution, Evol Appl, Funct Ecol, Glob Chang Biol, Glob Ecol Biogeogr, J Anim Ecol, J Appl Ecol, J Biogeogr, J Ecol, J Evol Biol, Methods Ecol Evol, Mol Ecol, Mol Ecol Res, Plant Cell Environ*	Varies by journal
The Company of Biologists	*Biology Open*	$2160	*Development, J Cell Science, J Exp Biol, Dis Model Mech*	Varies by journal
AAAS	*Science Advances*	$2900†	*Science*	None

* A 20 per cent discount applies when manuscripts are transferred via the Manuscript Transfer Program.

† Discounts or surcharges may apply. Listed here is the expected average APC for 2016.

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industrialized countries that were members of the OECD and developing countries that were not members of the OECD in 1992.[12] We use OECD membership in 1992 rather than current membership because longer-term investment in scientific research is necessary for the purpose of scientific development. For each group (developing and industrialized countries) we chose the five countries with the highest number of publications in *PLOS ONE* from 2011 to 2015. None of the countries with developing economies included in our analysis were eligible for the PLOS Global Participation Initiative, which provides a partial or full fee waiver for researchers who may be unable, or have limited ability, to pay to publish in open access journals.

We compiled data for each journal for the total number of publications and the number of publications per country from 2011 to 2015 (see Appendix 1). The data were retrieved by searching on the Web of Science Core Collection using the functions *publication name* and *time span* and subsequently refining the results using the *countries/territories* filter. Data on publications in *Science Advances* were retrieved from PubMed because this journal is not listed on Web of Science. Also, *Science Advances* started publishing in 2015, and so data were collected for only one year for this journal. Multi-author publications were attributed to multiple countries according to the authors' affiliations. Note that the count of publications assigned by country is higher than the total number of publications counted and higher than the count would be if each paper were assigned to only one country. Non-primary scientific publications such as editorial material, news items, biographical items, book reviews, corrections, and proceedings papers were excluded from the data set, leaving only articles, reviews, and letters (in Nature Publishing Group journals) included in the analysis. We then expressed the number of publications per country as a proportion of the total number of publications in each journal. In cases where multiple premium journals were affiliated with a single mega-journal, we averaged the proportion of publications across premium journals.

For the statistical analyses, we calculated the difference between each country's proportion of publications in the mega-journal and in the premium journal(s) for each tandem set. To fulfill normality assumptions, a square-root transformation was performed on the absolute value of the data. We then performed a full factorial ANOVA with *socio-economic status* (industrialized/developing) and *publisher* as factors using the lm

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function in R 3.2.4.[13] Normality of the residuals was checked visually in a QQ-plot and with a Shapiro–Wilk test.

RESULTS

The number of publications in mega-journals has risen exponentially over the last decade. *PLOS ONE* has surged in publication numbers, with 137 in 2006, 13,782 in 2011, and 28,116 in 2015. During the same period, publication in its associated premium journals *PLOS Biology* and *PLOS Medicine* remained relatively constant (306 in 2011, 280 in 2015). Similarly, Nature Publishing Group's *Scientific Reports* increased its number of publications from 205 papers in 2011 to more than 10,000 publications in 2015, and again doubled the number of publications in 2016. In contrast, publications in *Nature* remained stable at just over 1100 publications per year. An increasing proportion of the mega-journal publications come from countries with developing economies. In particular, China is quickly narrowing the scientific productivity gap, having produced over 19 per cent of the *PLOS ONE* articles that were published in 2015 and close to 40 per cent of the publications in *Scientific Reports*. Other developing countries also showed growth but with substantially lower numbers: for example, in 2015 the Republic of Korea published 3.4 per cent and 5.9 per cent of the papers in *PLOS ONE* and *Scientific Reports*, respectively.

However, the leading role of Chinese science in mega-journal publications is in stark contrast with its share in the premium journals. For instance, in the PLOS flagship journals only 5.5 per cent resulted from Chinese research, and this trend was similar for other countries with developing economies. In contrast, in these high-end PLOS journals, the hegemony of European and North American science is especially strong. The most prolific were US and UK scientists, with involvement in 56.2 per cent and 30.0 per cent, respectively, of the total *PLOS Biology* and *PLOS Medicine* publications compared to only 33.5 per cent and 8.6 per cent in *PLOS ONE*.

Our analysis showed that socio-economic status was a highly significant factor for the difference in proportion of publications in mega-journals versus premium journals (Figure 1). Industrialized Western countries had a significantly larger share of the publications in premium journals compared to mega-journals, whereas this was reversed for countries with developing economies (socio-economic status: $F_{1,40} = 53.76$; $p < 0.001$).

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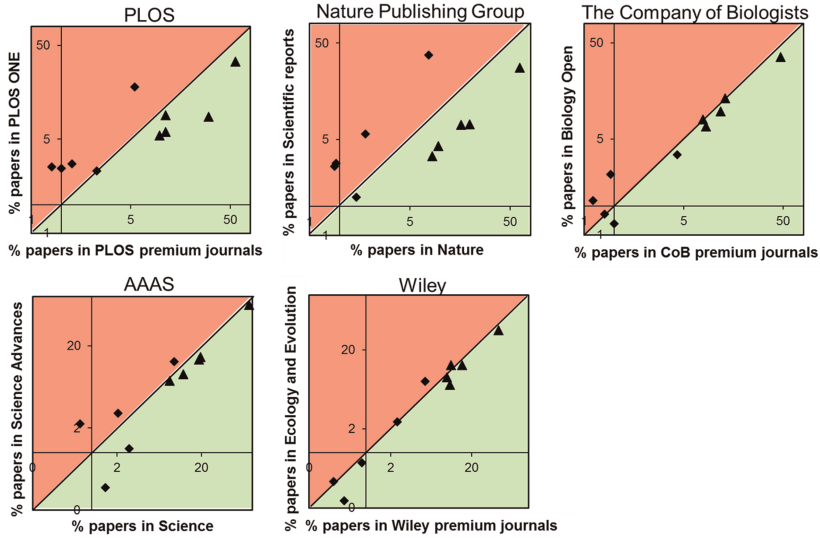

FIGURE 1. The percentage of publications of industrialized (triangles) and developing (diamonds) countries in mega-journals compared to the premium journal(s) of the same publisher. The diagonal line denotes an equal share of articles in the mega/premium tandem set. The area right of the diagonal (dark grey in print and green online) indicates a lower share of articles in the mega-journal than in the premium journal(s); countries in this area of the graph profit from cross-financing publication fees. The area left of the diagonal (light grey in print and red online) indicates a larger share of articles in the mega-journal than in the premium journal(s); countries that fall into this range suffer from cross-financing publication fees. For graphing purposes, data are plotted on a logarithmic scale.

This pattern was consistently present for all tandem sets of journals, independent of publisher (publisher: $F_{4,40} = 0.24$; $p = 0.91$).

As a consequence, countries with developing economies unequally contributed publication fees to the mega-journals to subsidize the premium journals that favour publications from Western countries, who thus profit maximally from the cross-financing. The strength of the socio-economic bias varied between publishers, as indicated by the significant interaction between socio-economic status and publisher ($F_{4,40} = 4.55$; $p = 0.004$). A post-hoc comparison showed that Nature Publishing Group and PLOS had a significantly larger global inequity in the proportion of publications than Wiley and the Company of Biologists (*t*-test, all comparisons $p < 0.05$).

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DISCUSSION

The popularity of OAP comes from the many benefits of the practice that pervade academia. However, our study identifies some of the associated pitfalls, which have not yet received attention within the scientific community.

Global Inequity in Gold OAP Fees

Our results show that the financial ramifications of gold OAP are biased toward Western academics, as institutions and researchers from developing countries disproportionately bear the costs of APCs for open access mega-journals compared with Western industrialized countries. These results of socio-economic inequity hold across five different mega-journals, showing that the problem is common. Of course, this disparity between the publishing trends of developing and Western countries is not the product of conscious decision by the mega-journals; more likely it reflects a variety of other socio-economic forces. But whatever the mechanism, the end result is that research funds from developing economies are ultimately funneled to support the scientific advances of Western science in top-ranked flagship journals. We feel that the overpriced publication fees for mega-journals, coupled with the unequal global distribution of the financial burden these fees incur, violate the egalitarian principles that underlie open access.

There are a number of potential explanations that might qualify our interpretation of inequity in the trends we observed. First, it is possible that the publishing infrastructure in many developing countries is less established than that in most Western countries and that publishing in the journals of developed countries is the only option available to researchers in developing countries who want to disseminate their findings broadly. Although the paucity of local publishing options may explain the increase in scientific contributions from developing countries, it does not justify the unequal subsidizing burden brought about by the two-tiered system of mega-journal publishers.

A second explanation could be that many publishers waive APCs for developing countries altogether and that this may mitigate the financial burden of cross-subsidy from mega-journals to premium journals. For example, PLOS has the Global Participation Initiative, which, as already mentioned, is an assistance program for researchers who are funded by institutions in low- or middle-income countries, designed to decrease

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the barrier to publication that comes from lacking funds for APC payment. Obviously, such initiatives should be endorsed and can help lower the barriers to publication for scientists in developing economies. The compensatory effect of waiver programs on cross-subsidizing is, however, small. Again, with PLOS as an example, less than 5 per cent of the income in publication fees is provided in fee assistance programs, and this figure includes the entire suite of PLOS journals (not only *PLOS ONE*) and also includes assistance other than that provided by the Global Participation Initiative.[14] Moreover, none of the countries with developing economies included in our analysis were eligible for the PLOS Global Participation Initiative.

A third possible explanation that may qualify our findings to some extent is that the developing countries we tracked may have strong publishing policies that promote OAP. China is the most prominent developing economy in our study with a disproportionate share of mega-journal publications. It is possible that the Chinese government has an explicit strategy to prioritize investment in scientific research and increase output through gold OAP. Nevertheless, this argument does not overturn our conclusion that developing countries are subsidizing the two-tiered APC model that allows the top journals to thrive, to the benefit of developed countries.

So, why has the popularity of mega-journals as a publication outlet thus far remained intact? It is possible that most contributors are unaware of the financial implications because institutions often have arrangements with publishers to cover, in part or in full, APCs for authors in their employ. Publishers also profit from the three-year lag in Impact Factors that makes perceived status difficult to verify with quantifiable impact. In addition, even for well-informed authors, the increasing publication pressure and tenure requirements often leave them little choice but to seek outlets where they can publish their research quickly and abundantly. For example, in China there is an extraordinary emphasis put on publications, which are often awarded with cash prizes.[15] As increased pressure to publish is a general pattern in academia, it makes the high acceptance rates and rapid review system of mega-journals increasingly attractive. Finally, gold OAP is heavily sponsored by research funding agencies and policy makers who endorse the expansion of gold open access journals as part of their OAP goals.

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Need for Financial Transparency in OAP

Given that open access is the future for scientific publishing, monitoring and regulating its financial implications are more important now than ever before. At present, many funding agencies allocate significant amounts of research money to cover APCs but have thus far failed to set any criteria for the financial transparency of OAP. Indeed, a recent survey by Science Europe, an association of European Research Funding Organisations and Research Performing Organisations, addresses the issue of reimbursement of APCs and shows that by far the majority of national funding organizations in Europe provide APC funding without any standards for fairness of the publication fee or financial transparency.[16] This must clearly change, and the sooner the better.

We recommend that scientists collaborate more effectively with funding bodies to develop criteria for sound OAP that address the global implications of business models. We feel it is ethically dubious that cross-subsidizing by mega-journals leads to one country supporting part of the scientific costs of another country. Publication fees should reflect the real cost of publishing and should be transparent for authors. We need to revisit the financial aspects of OAP to ensure fairness and equity in the publishing process. These are necessary steps toward developing policies for sound OAP without sacrificing scientific quality.

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NOTES

1. M. Enserink, 'Dutch Push for a Quantum Leap in Open Access,' *Science* 352 (2016): 279, doi:10.1126/science.352.6283.279.
2. *Mega-journal* is a descriptive term, not a technical one. Decade-old *PLOS ONE* is the archetypal mega-journal, marked by its prodigious output of articles, its generalist scope, its APC-funded open access model, and its cross-subsidized affiliates. A blogger for the *Scholarly Kitchen* recently commented on *PLOS ONE*'s drop to second place in the mega-journal market after losing the distinction of being the world's largest journal to competitor *Scientific Reports* in the first quarter of 2017. In that quarter, *Scientific Reports* published 6214 research articles to *PLOS ONE*'s 5541. *PLOS ONE*'s slip from first place is evidence of its business model's success. Since *PLOS ONE* launched a decade ago, other publishers have entered the market with competing mega-journals of their own. See P. Davis, 'Scientific Reports Overtakes PLOS ONE as Largest Megajournal,' *Scholarly Kitchen* (blog), April 6, 2017, https://scholarlykitchen.sspnet.org/2017/04/06/scientific-reports-overtakes-plos-one-as-largest-megajournal/.
3. J. Bohannon, 'Who's Afraid of Peer Review?' *Science* 42 (2013): 60–65, doi:10.1126/science.342.6154.60.
4. R. Van Noorden, 'Open Access: The True Cost of Science Publishing,' *Nature* 495 (2013): 426–9.
5. B.-C. Björk, 'Have the "Mega-Journals" Reached the Limits to Growth?' *PeerJ* 3 (2015): e981, doi:10.7717/peerj.981.
6. D. Butler, 'PLoS Stays Afloat with Bulk Publishing,' *Nature* 454 (2008): 11.
7. Acceptance rates were taken in March 2017 from 'Journal Information,' *PLOS Medicine*, http://journals.plos.org/plosmedicine/s/journal-information; and 'Journal Information,' *PLOS Biology*, http://journals.plos.org/plosbiology/s/journal-information#loc-criteria-for-publication.
8. Björk, 'Have the "Mega-journals" Reached the Limits to Growth?'
9. Nature Publishing Group merged with Springer and now goes by the name Springer Nature. The merger happened in 2015, the last year of our data collection period, so we have used the former name applicable to our collection period.
10. Van Noorden, 'Open Access.'

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11. See, for example, the petition at http://petitions.moveon.org/sign/support-fair-open-access.
12. The list can be found at United Nations Framework Convention on Climate Change, 'Parties & Observers,' accessed August 26, 2017, http://unfccc.int/parties_and_observers/items/2704.php.
13. R statistical software is publicly available at R Project for Statistical Computing, https://www.r-project.org.
14. Publication fee assistance figures were found at PLOS, 'Fee Assistance,' accessed August 26, 2017, https://www.plos.org/fee-assistance#loc-fee-assistance-programs.
15. J. Qiu, 'Publish or Perish in China,' *Nature* 463 (2010): 142–3, doi:10.1038/463142a; H.-F. Yuan, W.-D. Xu, and H.-Y. Hu, 'Young Chinese Doctors and the Pressure of Publication,' *Lancet* 381, no. 9864 (2013): e4, doi:10.1016/S0140-6736(13)60174-9.
16. J.-C. Kita, N. Duchange, and A. Ponsati, 'Open Access Publishing Policies in Science Europe Member Organisations: Key Results from Science Europe and Global Research Council Surveys,' *Science Europe*, October 2016, https://www.scienceeurope.org/wp-content/uploads/2016/10/SE_OpenAccess_SurveyReport.pdf.

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APPENDIX 1: NUMBER OF PUBLICATIONS

Total number of publications and the number of publications per country (*n* [%]) in mega-journals (left column of each pair) and premium journals (right column) for the five-year period from 2011 to 2015. Note that *Science Advances* only started in 2015; hence its data are limited to that year.

Public Library of Science	*PLOS ONE*	*PLOS Biology* *PLOS Medicine*	Nature Publishing Group	*Scientific Reports*	*Nature*
US	42,532 (33.5)	836 (56.2)	US	5000 (27.7)	3586 (62.6)
UK	10,967 (8.64)	449 (30.2)	UK	1291 (7.15)	1137 (19.9)
GE	11,443 (9.02)	167 (11.2)	GE	1271 (7.03)	927 (16.2)
FR	7585 (5.98)	166 (11.2)	FR	770 (4.26)	553 (9.66)
CA	6920 (5.45)	145 (9.75)	CA	606 (3.35)	479 (8.37)
CH	22,779 (18.0)	82 (5.51)	CH	6760 (37.4)	444 (7.76)
BR	3467 (2.73)	19 (1.28)	BR	226 (1.25)	84 (1.47)
TA	3209 (2.53)	12 (0.81)	TA	474 (2.62)	51 (0.89)
RK	3095 (2.44)	15 (1.01)	RK	1029 (5.70)	104 (1.82)
IN	2929 (2.31)	34 (2.29)	IN	508 (2.81)	53 (0.93)
Total	126,887	1487	Total	18,067	5725

AAAS	*Science Advances*	*Science*	The Company of Biologists	*Biology Open*	Various CoB premium journals (see Table 1)
US	167 (62.8)	3004 (73.0)	US	219 (35.8)	3525 (47.0)
UK	39 (14.7)	722 (19.4)	UK	81 (13.2)	974 (13.0)
GE	36 (13.5)	700 (18.7)	GE	59 (9.64)	879 (11.7)
FR	20 (7.52)	329 (8.33)	FR	41 (6.70)	630 (8.39)
CA	24 (9.02)	461 (12.2)	CA	49 (8.01)	584 (7.78)
CH	34 (12.8)	314 (9.54)	CH	21 (3.43)	323 (4.30)
BR	3 (1.13)	89 (2.78)	BR	4 (0.65)	75 (1.00)
TA	6 (2.26)	35 (0.72)	TA	13 (2.12)	69 (0.92)
RK	0 (0)	56 (1.45)	RK	7 (1.14)	46 (0.61)
IN	8 (3.01)	57 (2.05)	IN	5 (0.82)	60 (0.80)
Total	266	4201	Total	612	7508

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Wiley	*Ecology and Evolution*	Various Wiley premium journals (see Table 1)
US	579 (35.7)	6461 (42.5)
UK	209 (12.9)	2292 (15.1)
GE	146 (9.01)	1496 (9.84)
FR	208 (12.8)	1688 (11.1)
CA	117 (7.22)	1640 (10.8)
CH	130 (8.02)	811 (5.33)
BR	7 (0.43)	61 (0.40)
TA	12 (0.74)	136 (0.89)
RK	40 (2.47)	368 (2.42)
IN	3 (0.19)	82 (0.54)
Total	1620	15,205

BR = Brazil; CA = Canada; CH = China; FR = France; GE = Germany; IN = India; RK = Republic of Korea; TA = Taiwan; UK = United Kingdom; US = United States