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Abstract

Many open access (OA) journals require authors pay an article processing charge (APC), which researchers in the Global South often cite as a major financial barrier. This has led to speculation that there will be lower representation of these authors in OA journals charging APCs. We used "Mirror journals" – APC-charging OA versions of subscription "Parent" journals with whom they share editorial boards and standards for acceptance – to investigate the relationship between APCs and the geographic diversity of authors. Most of the >36,000 articles we reviewed were published in Parent journals. Although lead authors were based in >140 countries, ~45% were based in either the United States of America (USA) or China. After correcting for differences in sample size, we found no difference between Mirror and Parent journals in the number of countries in which lead authors were based. However, after accounting for the dominance of China and the USA, we found that author diversity in Mirror journals was significantly lower than in Parent journals. Most OA articles were written by authors in high-income countries; no articles in Mirror journals had first authors from low-income countries. Our results are consistent with the hypothesis that APCs are a barrier to OA publication for scientists from the Global South.

Keywords: Open access, article processing charges, author diversity, geographic diversity, Global South, Mirror journals, Open Access

Word count: 4602

Article processing charges, the geographic diversity of author communities, and barriers to publication for authors in the Global South

1 Introduction

Open Access (i.e., OA) articles can be read without payment or subscription to the journal in which they are published, and the number of OA articles published annually has grown dramatically over the last two decades (Piwowar et al., 2018). In addition to benefiting readers without access to traditional subscription-based journals, open access publishing can also benefit an article's authors (reviewed in McKiernan et al., 2016; Tennant et al., 2016). For instance, OA articles can garner more online views, have higher download rates, and accrue more citations over time than articles in subscription outlets (Davis, 2011; Eysenbach, 2006; Wang, Liu, Mao, & Fang, 2015). Metrics such as these are increasingly taken into consideration when conducting performance evaluations of scientists, including the tenure and promotion process in academic institutions (Schimanski & Alperin, 2018). Publishing OA articles can therefore play an important role in a scientist's professional advancement and status (MacLeavy, Harris, & Johnston, 2020; McKiernan et al., 2016). This will be the case regardless of whether the article is in a journal where all articles are open access (i.e., a "Gold OA" journal) or a "Hybrid" journal that publishes both open-access articles and that are only available to subscribers. However, the professional value of OA is likely to be especially high for Gold OA journals that have other characteristics valued by evaluators: name recognition, high impact factor, perceived prestige, or association with certain academic societies (Gray, 2020; Schimanski & Alperin, 2018).

Publication in Gold OA journals is also increasingly required by government agencies and private foundations that fund research (Björk & Solomon, 2014; Pinfield, 2013). Scholars can publish at no expense in most Gold OA journals (Crow, 2009). However, the vast majority of OA articles are published in journals that require authors to pay an 'article processing charge' (APC) that helps defray the cost of journal operations (Gold OA journals) or offset lost subscription revenue (Hybrid journals) (Crow, 2009; Kozak & Hartley, 2013;

OpenAPC, 2020; Pavan & Barbosa, 2018; Piwowar et al., 2018). A recent survey found that for journals charging APCs - a list that includes the most prestigious and widely recognized OA outlets - the average APC was \$908 (± \$608 SD, N = 4418 journals), with 500 journals ~~charged~~ charging at least \$2000 and 12 journals charging APCs over \$4000 (Morrison, 2019; Singh & Morrison, 2019). For many researchers, especially those working in the Global South[1], these APCs are an insurmountable financial obstacle that prevents them from publishing in the most desirable OA outlets (Bahlai et al., 2019; Matheka et al., 2014; Peterson, Emmett, & Greenberg, 2013). This is true even for researchers with access to funding, as even modest APCs can consume a large fraction of their research budget (Pavan & Barbosa, 2018). Although publishers have attempted to address this with policies aimed at reducing or even waiving APCs for authors in some countries, many researchers in the Global South are ineligible for even partial waivers (Ellers, Crowther, & Harvey, 2017; Lawson, 2015, Table A1). This has led many to argue that the APCs allowing authors in low-income countries to read previously inaccessible journals are simultaneously excluding them from publishing in the same journals (Ellers, Crowther, & Harvey, 2017; Matheka et al., 2014; Poynder, 2019).

Despite the prevalence of this assertion, tests of how APCs shape author representation in the OA literature remain rare (Ellers, Crowther, & Harvey, 2017). This is largely because it has been challenging, if not impossible, to find journals for comparison whose primary difference is whether or not they charge APCs. ~~While~~ In 2018, however, the publishing company Elsevier introduced the concept of "Mirror Journals" – Gold OA versions of established Hybrid titles with identical editorial boards, peer review procedures, and standards for acceptance (Cochrane, 2018; Harrison, 2019). The goal was for this identical editorial structure, coupled with a nearly identical name (e.g., *Journal of Dentistry* / *Journal of Dentistry: X*, *Ecological Engineering* / *Ecological Engineering: X*), to elevate the visibility and status of the OA Mirrors to a level comparable to their Hybrid "Parent

[1] The world's 'developing' or 'emerging' economies primarily located in Latin America, Asia, Africa, and the Middle East (Brandt, 1980).

Journals" (Harrison, 2019), thereby attracting authors preferring or required to publish in a Gold OA journal. As with most Hybrid journals, there is no cost to authors publishing in the Parent Journal unless they want their article to be open access; the APC for doing so is identical to that charged by the corresponding Mirror journal (median = $2600, range = $1318–$3750, Table 1). Mirror and Parent journals are cross-promoted on each others' websites, as are the publishers APC waiver policies.

The Parent-Mirror system is an ideal 'natural experiment' with which to test for associations between APCs and author diversity. First, it eliminates three of the major factors that have hampered prior comparisons of OA and subscription journals: between-journal differences in aims and scope, potential author base, and the editorial process and criteria with which manuscripts are evaluated. Indeed, several of the journal websites emphasize that articles are processed with neither editors nor referees aware of whether an article was submitted to the Parent or Mirror journal. Furthermore, each Parent-Mirror pair has the same editorial board, which eliminates potential biases resulting from author-editor relationships. Finally, one can compare the authors of articles in the Mirror journal with those of the Open Access and the Subscription-only articles in the established Parent journal. This comparison can be used to assess whether any Parent-Mirror differences could actually be due to factors other than APCs that also shape author submission decisions, such as journal impact factor, national incentives, prior experience with the Parent journal, or limited familiarity with Mirror journals.

We used data from over 37,000 articles published in 38 Parent journals and their respective Mirrors to investigate the relationship between APCs and the geographic structure of author communities. We test three predictions: First, that the lead authors of OA articles in Mirror journals would be similar in geographic diversity and structure to the authors of OA articles in Parent journals. Second, that the geographic diversity of lead authors in OA articles in both Mirror and Parent journals would be lower than that of subscription-only articles in Parent journals. Third, that any such reductions would be due

to OA articles having fewer lead authors from low-income countries. We tested these hypotheses using diversity indices derived from information theory that are commonly used across disciplines for quantifying and comparing the structure of groups (Calver, Bryant, & Wardell-Johnson, 2018; Espin et al., 2017; Magurran, 2004). In doing so we not only provide a robust analysis of the association between APCs and author representation, but also the first comparison of author communities in the Mirror-Parent publishing framework.

2 Methods

In July 2020, we downloaded the complete reference records for all "Articles" and "Reviews" published in 38 Mirror journals (Table 1) from the Web of Science Core Collection and SCOPUS databases. We then identified the date of the first publication in each Mirror journal and downloaded the records of all articles published in the corresponding Parent journal from that date through July 2020 (Table 1). Each article from the Parent journals was identifying as being either OA or "paywalled," i.e., requiring a subscription or payment to read. Finally, for all papers we identified the country in which the first author's primary institution was located and assigned the country to its respective World Bank Region[2] and Lending Group[3] (World Bank, 2020).

To quantify the geographic structure of our focal author communities we used a diversity index derived from information theory. The most commonly used diversity metrics are calculated using two pieces of information. The first is Richness (R), which is the number of distinct categories contained in a sample (e.g., the number of countries in which authors from a group of journals are based). The second is Evenness, which is the relative frequency of each category in the sample (i.e., the relative proportion of authors based in each country). A robust and widely used diversity index is the reciprocal transformation of Simpson's Index:

[2] Europe/Central Asia, East Asia/Pacific, Latin America/Caribbean, Sub-Saharan Africa, South Asia, Middle East/North Africa, North America (i.e., Canada, United States).

[3] High Income (per capita GNI > $12476, including both Organization for Economic Cooperation and Development (OECD) member and non-OECD member, Upper-middle income (per capita GNI $4036–$12475), Lower-middle income (per capita GNI $1026–$4035), Low-income (per capita GNI < $1025)

$$D_2 = \frac{1}{\sum_{i-1}^{R} p_i^2}$$

where R is the maximum value of Richness, and p_i is the proportional abundance of type i during time interval t. Values of D_2 calculated for different groups are directly comparable; larger values of D_2 indicate greater diversity, with the maximum potential diversity equal to the highest value of Richness in the group (Magurran, 2004).

We began by comparing the geographic diversity of authors publishing in OA Mirror journals with that of authors publishing OA articles in Parent journals (Prediction 1) using permutations tests. We found no difference in the geographic diversity of authors of these two groups of OA articles (Table A1, Figure A3).

The number of OA articles in both parent and mirror journals precluded robust comparisons of Geographic Diversity for journal pairs. We therefore calculated and compared the Geographic Diversity (D_2) of lead authors at the level of 'article type' (i.e., Subscription vs. OA). It is important to note, however, that we cannot simply pool the OA and Paywalled articles from the different journals and compare the resulting Diversity scores of the different groups. This is because there were 12-fold more PW articles than OA articles, and Richness, which is used to calculate (D_2), increases with ~~with~~ sample size. Furthermore, any analyses conducted on a collection of articles drawn from multiple journals would be skewed by patterns in the journals with most articles. We therefore used abundance-matched bootstrapping (Efron & Tibshirani, 1994) to compare the geographic diversity of the pooled open access articles with that of 1,000 different collections of paywalled articles. These collections were generated by counting the number of articles published in each OA Mirror, then randomly sampling with replacement an identical number of ~~Paywalled~~ articles from the respective Parent journal (Fox, 2015). To determine if the Geographic Diversity of OA and PW articles were significantly different we calculated $\hat{P}$ – the proportion of PW collections whose value of D_2 was below that of the OA collection. A $\hat{P} > 0.975$ indicates the Diversity of the OA collection is significantly greater than that of the PW samples; OA Diversity is significantly lower than that of PW samples when $\hat{P} < 0.025$. The same

procedure was used to compare the proportion of Paywalled and OA articles written by authors in different global regions and national income categories. The analyses above were conducted for two types of lead authors: (1) the authors of single-authored papers, and (2) the first authors of co-authored papers. We analyzed single- and co-authored papers separately because of the potential insights into financial constraints that could emerge from divergent results for these author types: while the APC for a single-authored paper is the responsibility of one person, the APC of a co-authored paper can potentially be divided among – or even paid entirely by – co-authors with access to funding.

Simpson's Index is robust to moderate differences in sampling effort. However, it is sensitive to how equitably samples are distributed between categories (i.e., it is a 'dominance' or 'evenness' index, Magurran, 2004), meaning more dominant categories will have disproportionately greater effects on D_2. Failure to consider this effect can lead to incorrect inference regarding differences in diversity, especially in cases where dominance is most pronounced. This is because a small number of dominant categories can dramatically lower D_2 even if the number of remaining categories and their proportional representation are identical. Put another way, dominant categories "suppress" the contributions to diversity of the other categories in a group.

Because over 40% of first authors were based in either China or the United States (Fig. A1), we sought to assess if this dominance could be biasing estimates of author diversity. To do so we conducted a series of simulations in which we sequentially removed authors from each country and measured the resulting change in D_2. China was the only country whose exclusion led to increased diversity, with a relative effect on D_2 that was 142 times that of any other country (Fig A2). We then excluded all papers with first authors based in China and repeated our simulations. Diversity only increased (8-fold) when excluding articles with first authors based in the USA, with a relative effect on diversity that was 31 times greater than that of any other country (Fig A2). These results indicate that there is a large and negative bias in D_2 when including authors from the USA and China in analyses. We

therefore conducted all analyses both with and without authors ~~forom~~ from these two countries. We also repeated all analyses with Shannon's Index, which is somewhat less sensitive to extreme differences in relative frequency than Simpson's Index. Results for Simpson's and Shannon's indices were qualitatively similar (Fig. A2), so we present here only the results for Simpson's Index.

All data analyses were carried out with code written in the R statistical programming language (R Core Team, 2020). We used the **refplitr** (Fournier, Boone, Stevens, & Bruna, 2020) and **bibliometrix** (Aria & Cuccurullo, 2017) libraries to process the Web of Science and SCOPUS records (respectively) and georeference lead authors. We used the online **MapAffil** tool (Torvik, 2015) to manually georeference the 141 addresses that these packages were unable to georeferenced automatically. Richness and Diversity were calculated with the **vegan** library (Oksanen et al., 2019), while **ggplot2** (Wickham et al., 2019) was used for all data visualizations[4].

3 Results

The 38 Mirror journals published 975 articles from their inception through the date we downloaded the article records. During the same interval, their respective Parent journals published 36112 articles, of which 1819 were open access (Table 1). Single-author publications accounted for 21% of the articles in Mirror journals (N = 202), but only 2% of articles in Parent journals (N = 747). Lead authors were collectively based in 142 countries, with authors from N = 38 countries in Mirror journals, authors from N = 15 countries in Parent journal OA articles, and authors from N = 15 countries Parent journal PW articles. While 45% of articles had a lead author whose primary institutional address was in either the United States of America (USA) or China (Fig. A1), there was an important difference among journal types in the representation of authors from these two countries. While USA authors published approximately 2-times more OA articles than authors based in China,

[4] Available at https://github.com/embruna/APCdiversity for review and improvement; the version used for this manuscript will be permanently archived at Zenodo and included in the References upon acceptance.

authors from China published 3-times more Paywalled articles than authors from the USA (Figs. 1, 2).

3.1 Geographic Diversity

First Authors of co-authored articles: Author geographic diversity ~~as~~ was lower for PW than OA articles when all countries were included in the analyses. The pattern was reversed, however, after correcting for the dominance of authors based in the USA and China – author geographic diversity of both Mirror journals and OA articles in Parent journals was significantly lower than that of PW journals ($\bar{D}_2^{PW} = 24.52 \pm 1.4$ SD, $D_2^{Mirror} = 17.7$, $D_2^{OAinParent} = 16.5$; Fig. 3, Table 2). *Sole-authored articles:* The results for sole-authored articles were more complex. OA articles in Parent journals had significantly lower author diversity than PW articles in Parent journals whether or not China and the USA were included in the analyses (Fig 3). In contrast the values of D_2 for Mirror journals - while lower than for ~~for~~ PW articles in Parent journals were not significantly different for either the "All Countries" or "China and USA Excluded" comparisons (Fig. 3, Table 2).

3.2 Global Regions and National Income Categories

When correcting for differences in sample size by bootstrapping, we found that OA articles in Mirror journals had significantly more authors from North America and the East Asia / Pacific region than PW articles in Parent journals. They also had significantly fewer authors from Latin American and the Caribbean, the Middle East and North Africa, and Sub-Saharan Africa (Fig. 4, Table 4). Consequently, the authors of articles in Mirror journals were significantly more likely to be based in high-income countries (Fig. 5, Table 5), while authors from middle-income countries were significantly underrepresented. Overall, a nearly identical proportion of Paywalled articles in Parent journals had first authors based in upper-middle and high-income countries (47.3% and 47.5%, respectively). In contrast, an overwhelming majority of articles in Mirror journals were written by first authors based in high-income countries (81%; Fig. A3).

The dearth of lead authors from low-income countries was especially notable. None of the 975 articles in Mirror journals had first authors from low-income countries. Only **XX%** of the articles in Parent journals were written by lead authors based in low-income countries; of these the overwhelming majority were subscription-only articles in Parent journals (**N = 41 of 54**) (Fig. 1B). Across all journal and article types there were **XX** different low-income countries were represented, with **country** ~~was~~ as the primary contributor. (Fig. 2B).

4 Discussion

One of the central tenets of open access publishing is that it helps make the scientific community more globally inclusive. This is considered particularly beneficial to scientific communities with limited financial resources, such as those in many countries of the Global South. While this benefit is undisputed, it has been suggested that OA publishing can also have unintended negative consequences for the same communities. Chief among these is that the funding model used by the most widely recognized and prestigious open access journals – a reliance on article processing charges – allows for readers with limited financial resources to access the scientific literature, but also prevents them from contributing to it. We found that author geographic diversity was far lower when comparing open access with subscription-only articles, regardless of whether the OA articles were published in Mirror or Parent journals. We also found that an overwhelming majority of open access articles in both Parent and Mirror journals had lead authors based in high-income countries. Of the small number of articles by authors based in low-income countries, most were subscription-only articles in Parent journals. Taken together, these results are consistent with the hypothesis that APCs are a barrier to Open Access publication by scientists from low-income countries.

We gained unique insights into the geographic diversity and structure of author communities by using an index that accounted for the proportional representation of different countries (i.e., "evenness"). It is important to remember, however, that all members of a category are treated as functionally equivalent when calculating these indices. This

means, for instance, that the number of countries represented in different article or journal categories can be identical even if the specific countries publishing in each are entirely different. Similarly, a more even distribution of authorship reveals nothing about the types of countries whose proportional representation has increased – only that the pattern of national dominance has become less skewed. Although authors of articles in Mirror and Parent journals were based in similar numbers of countries, the specific countries in which they were based were markedly different. Open Access articles had a far higher proportion of authors from North America, Europe/Central Asia, and the East Asia/Pacific region than similarly sized collections of Paywalled articles (Fig. 5). This is in sharp contrast to the paywalled articles ~~in Parent journals,~~ where proportionately more authors were based in Sub-Saharan Africa, South Asia, the Middle East/North Africa, and Latin America/The Caribbean. Consequently, authorship of OA articles was overwhelmingly concentrated in high-income countries, with proportionately fewer authors from middle-income countries (Fig. 6). For instance, the 15 most 'productive' countries of subscription-only articles included 7 in the World Bank's middle-income categories: China, India, Brazil, Iran, Turkey, Russia, and Mexico (Fig. 2B). In contrast, the top-15 countries of OA articles in Parent and Mirror journals combined included only five middle-income countries: China, India, Brazil, Mexico, and Egypt (Fig. 2A).

Perhaps the most surprising result of our study was the dearth of articles by authors from low-income countries (see also Nuñez et al., 2019; Stocks, Seales, Paniagua, Maehr, & Bruna, 2008). Of the more than 37087 we reviewed, only 0.013% (N = 54)**[convert to code]** had lead authors based in low-income countries. Most other articles were in Parent journals, all but two **[check]** were coauthored articles. Almost half of these articles (44%) had first authors based in Ethiopia, North Korea, Nepal, or Syria; the remainder were based in 19 other countries, mostly in Sub-Saharan Africa **[check these countries]**. While previous studies have documented geographic variation in rates of open access publication, including very low rates in some regions (Iyandemye & Thomas, 2019), these studies all

included OA journals in which authors could publish at no cost. The 38 OA journals we reviewed span disciplines from veterinary medicine to nutrition to waste management (Table 1); that there were zero papers with lead-authors from low-income countries, including from regions previously shown to have high rates of OA publication, further underscores the conclusion that authors in low-income countries are detrimentally affected by the financial burden of APCs. Previous research on author attitudes toward OA publishing has identified APCs as a barrier to publication, especially for independent researchers, students, and those at institutions focusing on undergraduate education (Coonin & Younce, 2009; Dallmeier-Tiessen et al., 2011; Warlick & Vaughan, 2007). We provide some of the strongest evidence to date that this is the case for researchers in the Global South as well (Appel, Albagli, Appel, & Albagli, 2019; Ezema & Onyancha, 2017; Ncayiyana, 2005). Although it is conceivable that the differences we observed are due to many of our focal journals having above-average APCs (Solomon & Björk, 2012b), we believe this is unlikely to be the cause. Authors in low-income countries are far more likely to use personal funds to pay APCs (Solomon & Björk, 2012a), and for many, even the average APC of $904 would consume a large fraction of their research budget (Ciocca & Delgado, 2017; Matheka et al., 2014; Wingfield & Millar, 2019), salary (Peterson, Emmett, & Greenberg, 2013), or student stipend (Table 3). Funds to defray publication costs are clearly available to some scientists in some of these countries (Pavan & Barbosa, 2018, Figs. 1 & 2); therefore, the most likely explanation for the observed results is that authors are actively choosing to publish at no cost in the PW journal instead of paying to publish in the OA Mirror (Ciocca & Delgado, 2017).

The lack of OA articles by authors based in low-income countries is particularly surprising given that most of these countries are eligible for waivers of APCs under the Elsevier's "Research4Life" program (Table A1). We suggest there are at least four potential explanations for this. The first is that publisher policies for waiving APCs can be quite restrictive. For instance, the publisher of the OA Mirror journals included in our review will only waive APCs in cases where every co-author of an article is based in a country that is

waiver-eligible (Elsevier, 2020). Many of the articles in our dataset with first authors based in low-income countries had international collaborators in locations that rendered the articles ineligible for discounted or free publication (see also Gray, 2020). Second, it may be that authors were unaware waivers existed or that journal or publisher staff failed to recognize their eligibility and offer to transfer their submission to the OA Mirror (Lawson, 2015). Third, authors may have been aware of the option to publish in Mirror journals at no expense, but nevertheless opted for publishing in the Parent outlets – perhaps because they view these as more prestigious (Ellers, Crowther, & Harvey, 2017). Finally, even large discounts on APCs are unlikely to be sufficient for many authors (Iyandemye & Thomas, 2019). This is almost certainly true for authors in countries that are bizarrely offered only partial discounts (e.g., Honduras, Guatemala) despite socioeconomic conditions that are similar to those in nearby countries where authors can publish OA at no expense (e.g., Nicaragua, Table A1). In absolute terms, however, the minimal benefit of partial waivers may be most pronounced for authors in middle-income countries – especially when they engage in productive collaborate with scientists based in middle-income countries such as Brazil, Mexico, South Africa, and Malaysia (Smith, Weinberger, Bruna, & Allesina, 2014) that are ineligible for waivers despite challenging economic conditions (Ciocca & Delgado, 2017). Regardless of the mechanism, our results suggest that waiver programs designed to increase the representation of scientists from the Global South in the OA literature by reducing APCs have at best failed to do so, and at worst had the opposite effect. Finally, our results also suggest there are some important differences in the way authors perceive Parent and Mirror journals. That there are some OA articles by authors from low-income countries in Parent journals but none in Mirror journals suggests a clear preference for more established titles. The same appears to be true for authors in the high- and middle-income countries where OA publishing is well-established - authors in these countries publish more OA papers in Mirror journals than their respective Parents (Fig 6). This skew is also notable given that Gold-OA publication is increasingly required by many of funders in some of these

countries (e.g., the UK), which has led to increased marketing efforts by Elsevier promoting Mirror journals. Finally, the results suggest authors in China and the USA either remain wary of OA publication or don't find the incentives for publishing OA particularly compelling. When these authors have opted for OA, they clearly prefer established Parent journals over the recently established Mirrors.

4.1 Caveats and Future Directions

Inference in bibliometric studies must be drawn with care, as patterns such as those we documented are the result of a complex combination of pre-submission decisions by authors and post-submission decisions by editors. Comparing OA articles published in Mirror journals to those published in Parent journals allows us to control for many of the factors that shape these decisions. Most notably, the journals in a Mirror pair have identical editorial boards, editorial philosophy, and publication priorities. While any implicit biases held by editors against authors from particular countries would undoubtedly reduce the overall representation of these countries in the literature, the reduction would be independent of the journal access category. As such, we believe our results reflect the outcome of pre-submission decisions by authors and are consistent with APCs being a central mechanism underlying them (Ciocca & Delgado, 2017; Solomon & Björk, 2012a). Our results also suggest several promising directions for future research. The first is to investigate why it appears scientists in some middle- and low-income countries, especially China and Brazil, overwhelmingly prefer to publish in subscription journals despite the apparent availability of funds to defray APCs. These academic communities might consider open access mirrors to be of lower quality, regardless of their affiliation with a known academic society, publisher, or connection to an established subscription journal (Editage, 2018). Alternatively, authors may be hesitant to consider them as outlets for their work because they do not yet have impact factors or other metrics used by their institutions in program evaluation (Appel, Albagli, Appel, & Albagli, 2019; Pavan & Barbosa, 2018; Xu et al., 2020). Second, our results suggest

there is a need for research on how to make waiver programs more effective, with particular emphasis on reducing financial barriers to OA publication for authors in middle-income countries. Answers to these questions will help editors, publishers, and the broader scientific community develop strategies to ensure prestigious open access journals are truly accessible to scientists from the Global South (Rodriguez, 2014).

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Table 1

Parent journals published by Elsevier included in this study, the number of open access and subscription-only articles published in each during our focal time-frame, the number of articles published in each Mirror during the same time period, and the article processing charge (APC) charged by each journal for OA publication. With two exceptions the titles of Parent and Mirror journals are identical except for the 'X' at the end of Mirror versions (e.g., Research Policy X, Optical Materials X).

Title	Parent Journal		Mirror Journal	
	Subscription	Open Access	Open Access	APC (US$)
Analytica Chimica Acta	1288	8	19	1850
Atherosclerosis	263	127	5	2308
Atmospheric Environment	1013	41	67	1400
Biochimie[1]	833	71	49	1318
Biosensors & Bioelectronics	1170	0	9	3500
Chaos, Solitons & Fractals	673	0	15	2200
Chemical Engineering Science	1021	22	45	3500
Chemical Physics Letters	1136	15	23	3050
Contraception	182	16	21	3200
Cytokine	424	46	7	3400
Ecological Engineering	437	18	13	2600
Energy Conversion & Management	1713	29	17	3100
European J of Obstetrics, Gyn, & Repro Bio	527	36	84	2500
Expert Systems With Applications	1061	22	10	2200
Food Chemistry	2992	49	44	2800
Gene	1079	14	21	3400
International J of Pharmaceutics	1291	36	38	3700
J of Asian Earth Sciences	595	6	10	2600
J of Biomedical Informatics	108	132	15	2350
J of Biotechnology	301	16	10	2820
J of Computational Physics	960	25	35	2800
J of Dentistry	207	16	5	3000
J of Hydrology	1412	42	37	3200
J of Non-Crystalline Solids	750	11	33	2200
J of Structural Biology	152	37	17	2750
Materials Letters	2493	12	30	2000
Microelectronic Engineering[2]	547	26	39	2020
Nutrition	415	25	2	2050
Optical Materials	1019	32	34	1500
Research Policy	194	50	2	2400
Respiratory Medicine	267	31	14	3500
Sleep Medicine	401	20	8	3360
Toxicon	271	7	26	3300
Vaccine	1014	479	42	2450
Veterinary Parasitology	221	17	21	3200
Water Research	2081	187	41	3750
World Neurosurgery	3440	29	43	2600
Resources, Conservation, & Recycling	551	69	24	3500
Total No. of Articles	34502	1819	975	

[1] OA Mirror title: Biochimie Open

[2] OA Mirror title: Micro and Nano Engineering

Table 2

Geographic Richness, Evenness, and Diversity of lead authors of papers published in Mirror journals, open access papers in Parent journals, and subscription-only papers in Parent journals. The value for Parent journals is the mean of 1000 bootstrap-generated article collections identical in size and structure to the articles in Mirror journals. Single: authors of single-authored papers; First: first authors of co-authored papers.

			All Countries			Without China & USA		
OA Source	Metric	Author	OA	Parent PW (mean ± SD)	$\hat{P}$	OA	Parent PW (mean ± SD)	$\hat{P}$
Mirror	Diversity	First	12.00	9.25 ± 0.69	0.013	17.70	24.52 ± 1.37	0.086
		Single	11.30	13.89 ± 2.34	0.668	17.40	22.56 ± 2.87	0.637
	Evenness	First	0.75	0.73 ± 0.01	0.000	0.81	0.85 ± 0.01	0.019
		Single	0.82	0.84 ± 0.02	0.000	0.89	0.92 ± 0.02	0.000
	Richness	First	60.00	61.05 ± 3.29	0.069	58.00	61.52 ± 3.2	0.000
		Single	38.00	43 ± 2.71	1.000	36.00	40.02 ± 2.63	0.000
Parent	Diversity	First	13.30	11.57 ± 0.52	0.687	16.50	24.33 ± 0.85	0.941
		Single	7.40	9.74 ± 3	0.500	10.30	9.9 ± 3.22	0.500
	Evenness	First	0.71	0.74 ± 0.01	0.000	0.76	0.83 ± 0.01	0.148
		Single	0.88	0.91 ± 0.06	0.000	0.95	0.93 ± 0.09	0.000
	Richness	First	85.00	70.46 ± 3.06	0.468	83.00	69.78 ± 3.14	0.397
		Single	15.00	15 ± 1.82	0.904	14.00	12.82 ± 1.45	0.000

Table 3

Monthly stipends for graduate students in select countries. The value of the stipend in US currency is based on the exchange rate in December 2020.

Country	Agency	Degree	Stipend (US$)
Brazil	CNPq[1]	MS/MA	294
		PhD	431
Mexico	CONACYT[2]	MS/MA	588
		PhD	783
India	SERB[3]	PhD[6]	747
		PhD[7]	978
Indonesia	RISTEKDIKTI[4]	MS/MA	195
South Africa	NRF[5]	MS/MA	670
		PhD	687

[1] http://cnpq.br/apresentacao13/

[2] https://www.conacyt.gob.mx/index.php/becas-y-posgrados/becas-nacionales

[3] http://www.serb.gov.in/pmfdr.php

[4] https://scholarshiproar.com/knb-scholarship/

[5] https://www.nrf.ac.za

[6] Min. value, Prime Minister's Doctoral Fellowship

[7] Max. value, Prime Minister's Doctoral Fellowship

I don't see the M or P used anywhere in the figures

Table 4

Percentage of Open Access articles with authors based in different World Bank Regions. The value for subscription-only articles in Parent journals (P) is the mean percentage of 1000 bootstrap-generated samples identical in size and structure to the collection of articles published in Mirror journals (M) collection. Single: authors of single-authored papers; First: first authors of co-authored papers; Significant differences between the value for articles in Mirror journals and bootstrapped samples from Parent journals are indicated with an asterisk.

Author	Countries	Region	Parent*	Mirror*	$\hat{P}$
Single	All Countries	East Asia & Pacific	15.54	18.34	0.863
		Europe & Central Asia	49.08	41.92	0.017*
		Latin America & Caribbean	8.73	2.62	0.01*
		Middle East & North Africa	14.31	5.68	0.003*
		North America	4.55	27.07	1*
		South Asia	2.97	3.49	0.725
		Sub-Saharan Africa	4.83	0.87	0*
First	All Countries	East Asia & Pacific	17.56	19.86	0.907
		Europe & Central Asia	44.76	46.69	0.775
		Latin America & Caribbean	10.56	3.76	0*
		Middle East & North Africa	14.77	2.33	0*
		North America	3.29	22.69	1*
		South Asia	4.55	3.31	0.173
		Sub-Saharan Africa	4.53	1.35	0*

Table 5

Percentage of Open Access articles with authors based in different World Bank Lending Groups. The value for subscription-only articles in Parent journals (P) is the mean percentage of 1000 bootstrap-generated samples identical in size and structure to the collection of articles published in Mirror journals (M) collection. Single: authors of single-authored papers; First: first authors of co-authored papers; Significant differences between the value for articles in Mirror journals and bootstrapped samples from Parent journals are indicated with an asterisk.

Author	Countries	Lending Group	Parent*	Mirror*	$\hat{P}$
Single	All Countries	High	NA	85.15	0*
		Lower middle	NA	5.24	0*
		Upper middle	NA	9.61	0*
First	All Countries	High	NA	77.50	0*
		Low	NA	0.49	0*
		Lower middle	NA	5.00	0*
		Upper middle	NA	17.01	0*

*should this be PW & OA?

should we explain that this is other high income countries excluding the ones above? This confused me at first

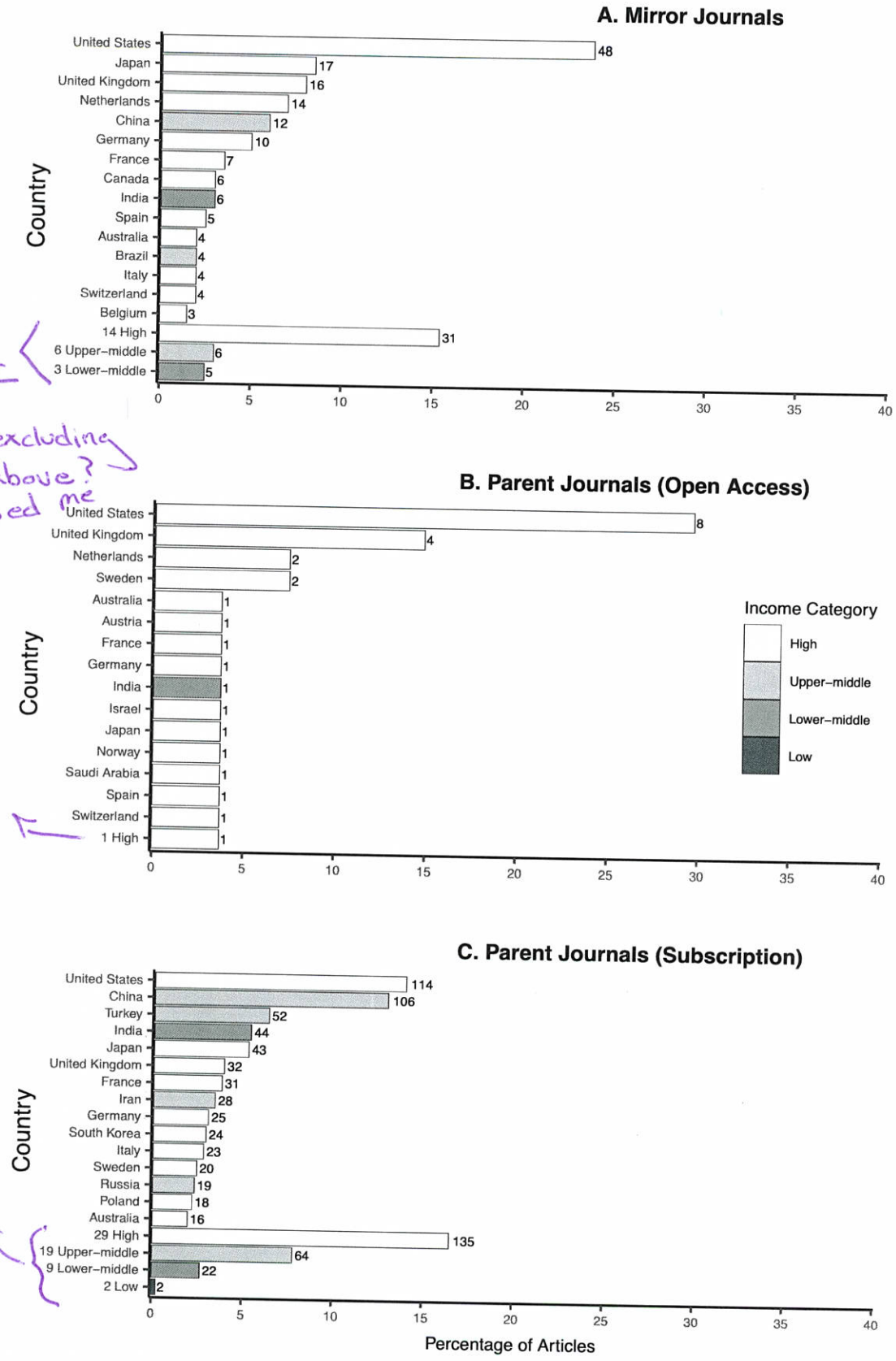

Figure 1. For single-author papers: (A) the percentage of authors of articles in Mirror journals that are based in different countries, (B) the percentage of authors of subscription-only journals in Parent journals that are based in different countries, and (C) the percentage of authors of subscription-only journals in Parent journals that are based in different countries. Numbers adjacent to bars are the number of articles with lead authors based in that country

same comment from F.1

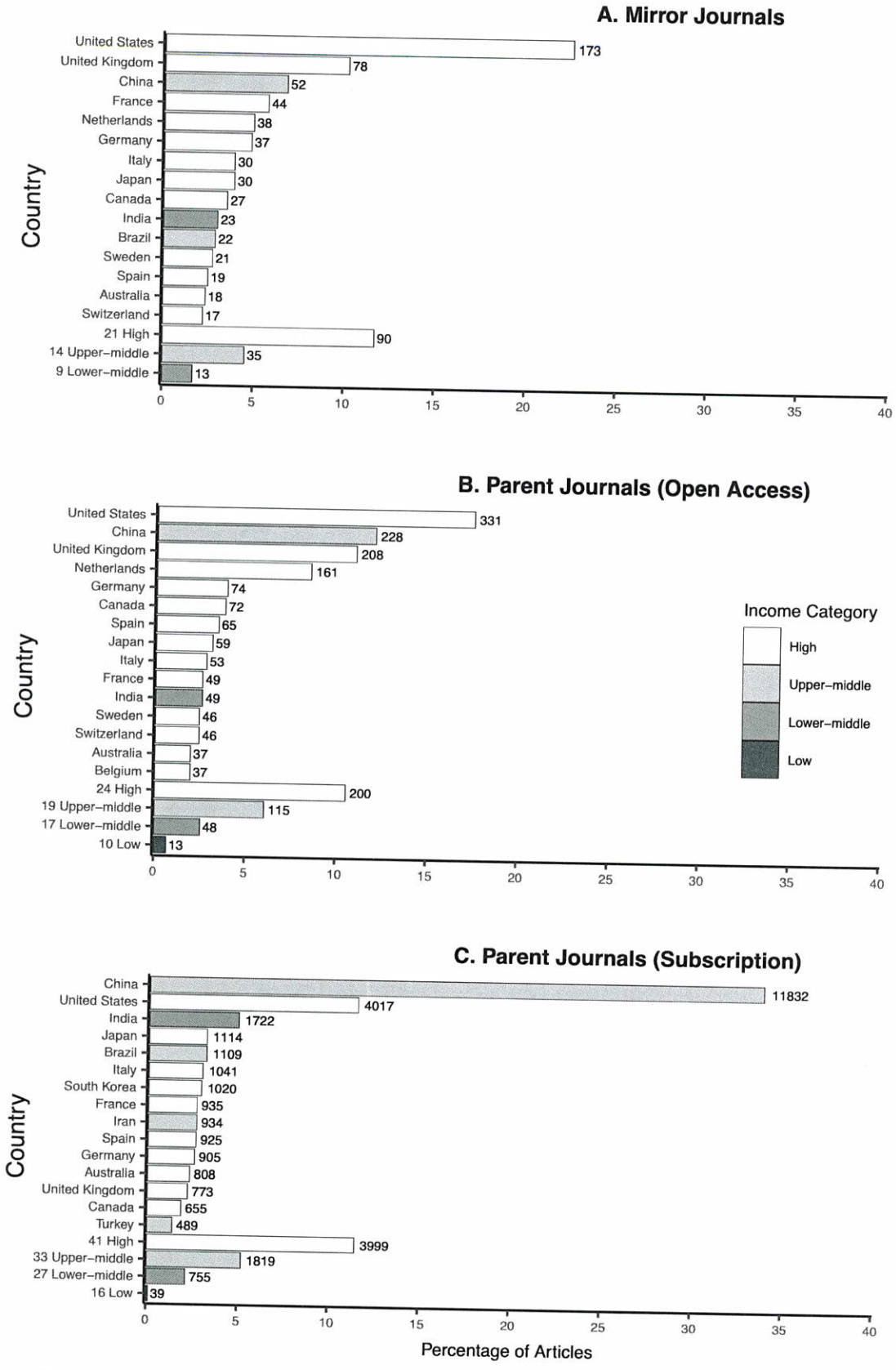

Figure 2. For coauthored papers: (A) the percentage of authors of articles in Mirror journals that are based in different countries, (B) the percentage of authors of subscription-only journals in Parent journals that are based in different countries, and (C) the percentage of authors of subscription-only journals in Parent journals that are based in different countries. Numbers adjacent to bars are the number of articles with lead authors based in that country. OS feature

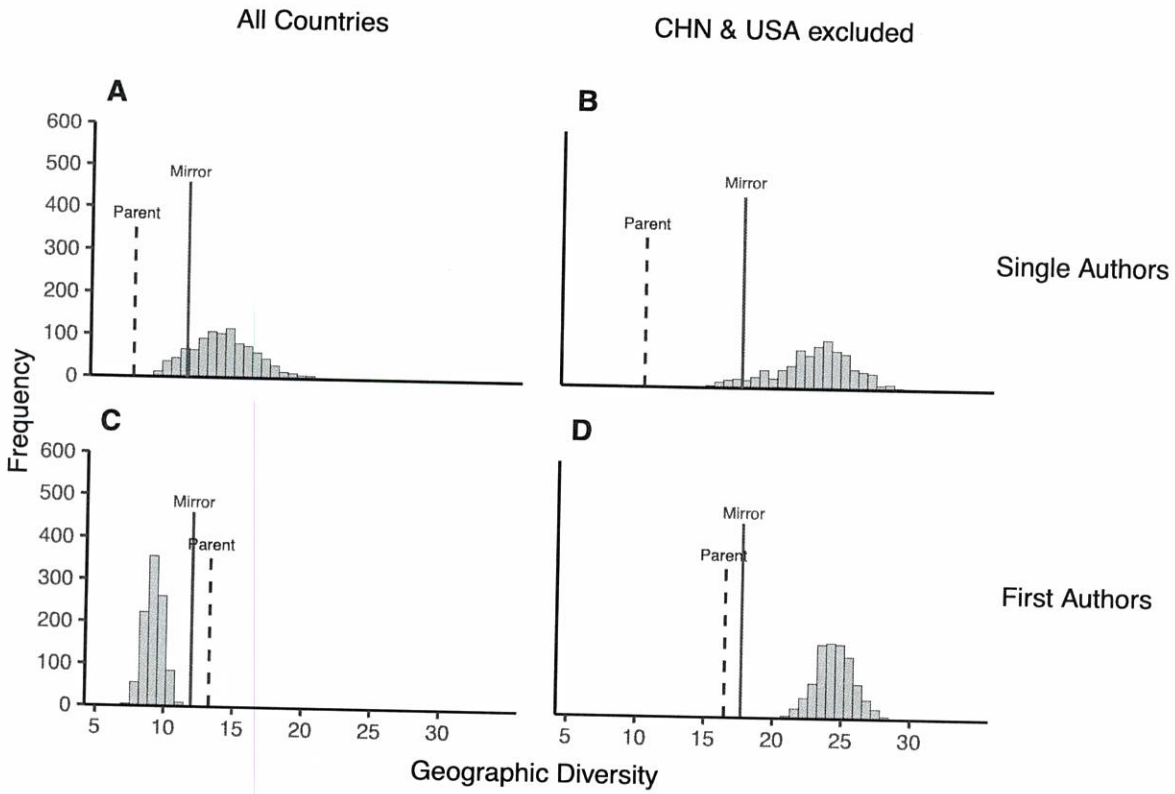

Figure 3. Author Geographic Diversity (D_2) for the open access articles in Parent journals (dashed line, N = 1819), articles in Mirror journals (solid line, N = 975), and 1000 collections of N = 975 subscription-only articles in Parent journals (sampled from N = 34293 total articles by bootstrapping).

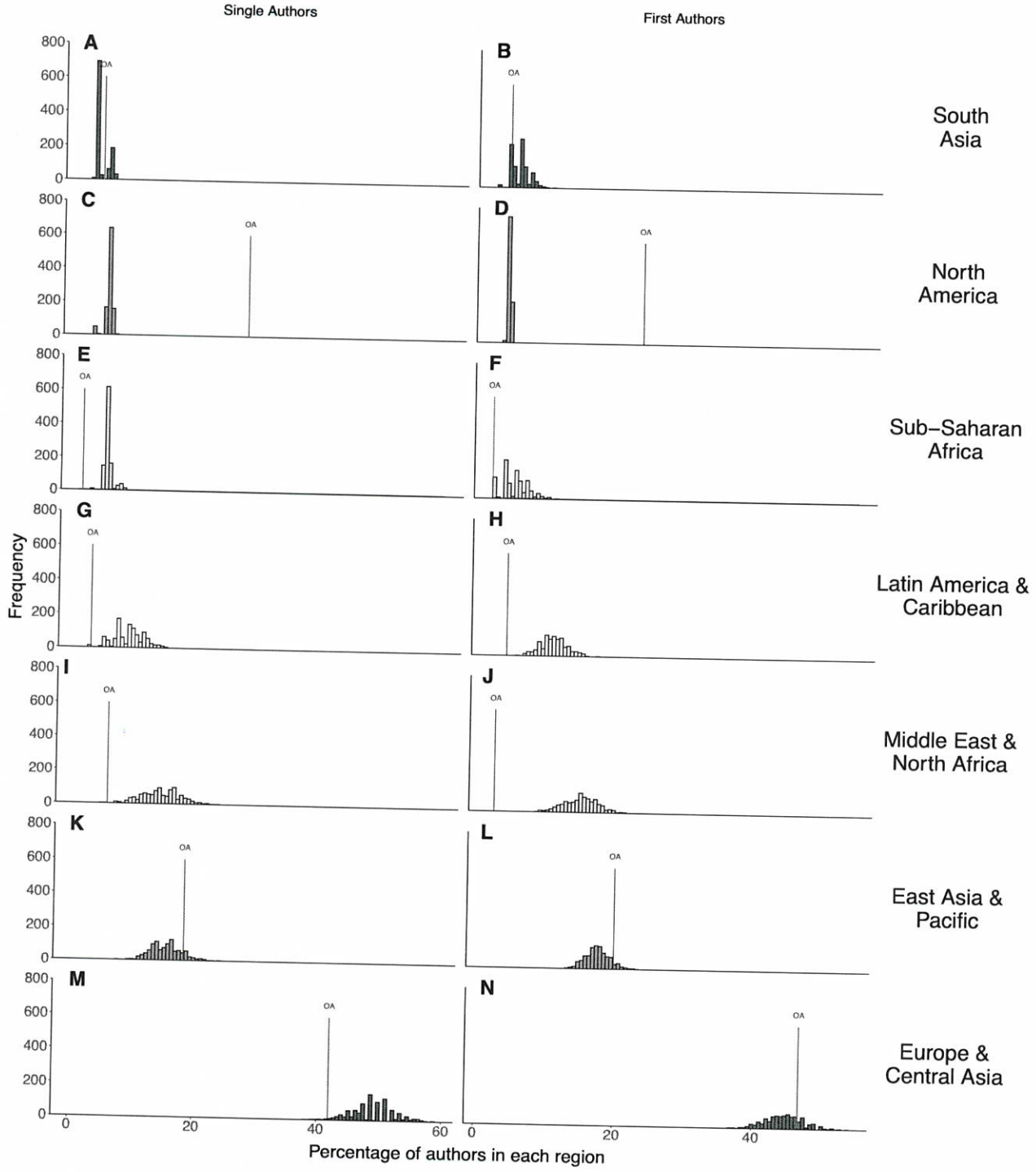

Figure 4. Percentage of first authors that are based in different global regions. The solid line is the value for N = 975 articles in Mirror journals; histograms are values for 1000 identically sized collections of subscription articles from Parent journals (sampled by bootstrapping from N = 34293 articles).

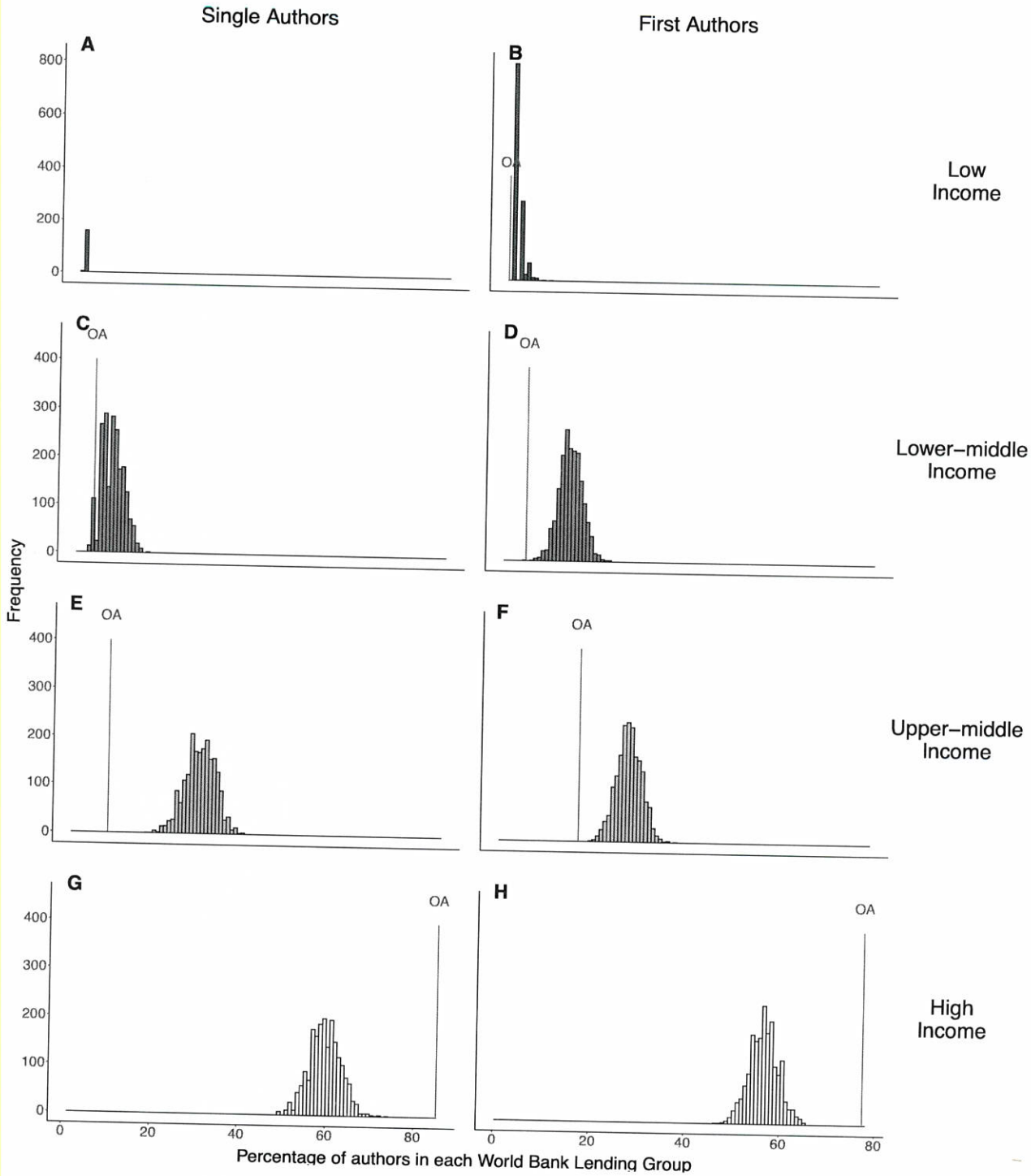

Figure 5. Percentage of first authors that are based in different World Bank Lending Groups. The solid line is the value for N = 975 articles in Mirror journals; histograms are values for 1000 identically sized collections of subscription articles from Parent journals (sampled by bootstrapping from N = 34293 articles).

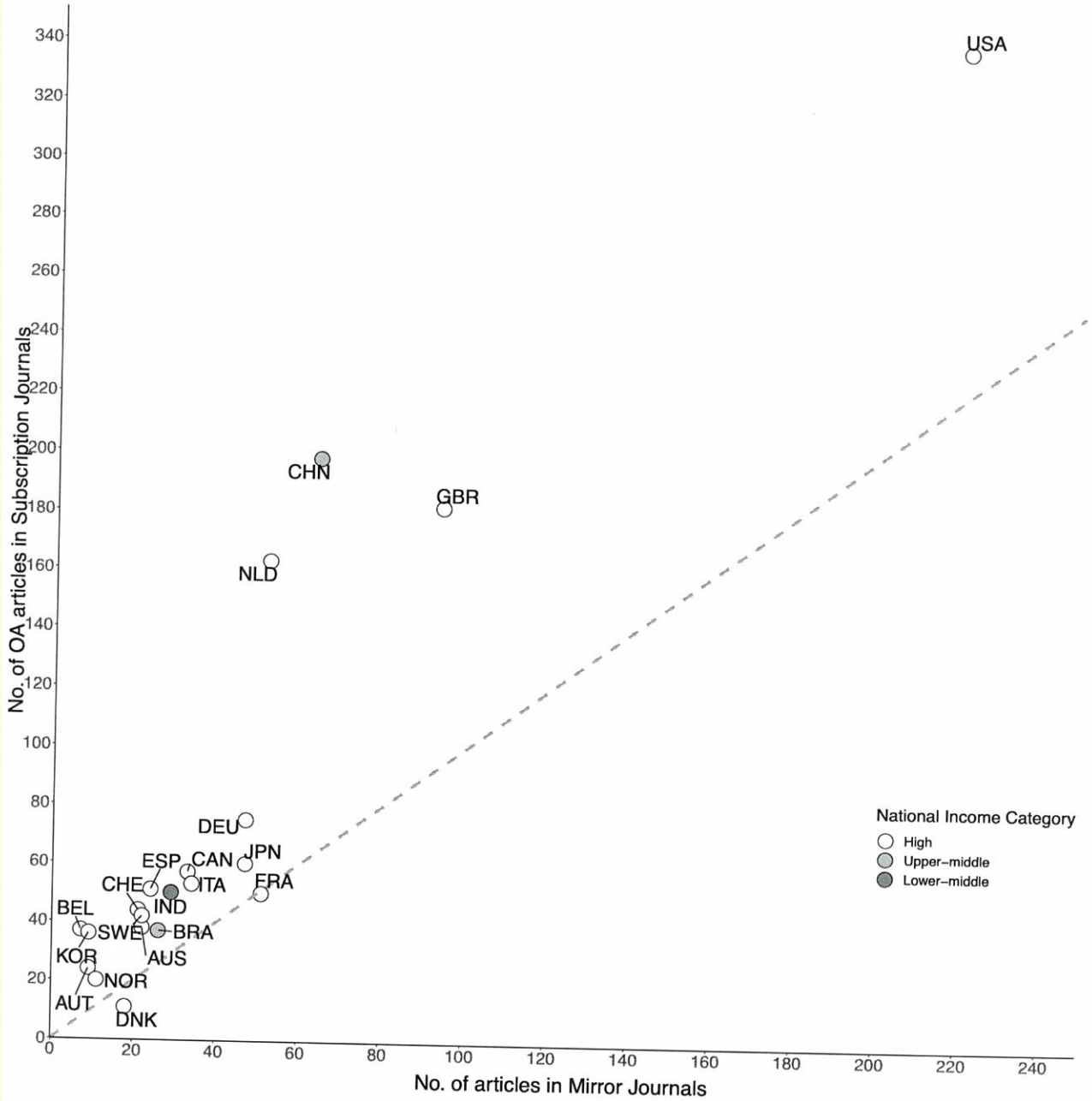

Figure 6. For the 15 countries publishing the most open access (OA) articles, the number of OA articles published in Mirror journals vs. Parent journals. The dashed line indicates equal numbers published in both journal types; countries above the line published more articles in Parent Journals than in the OA Mirrors.

Appendix

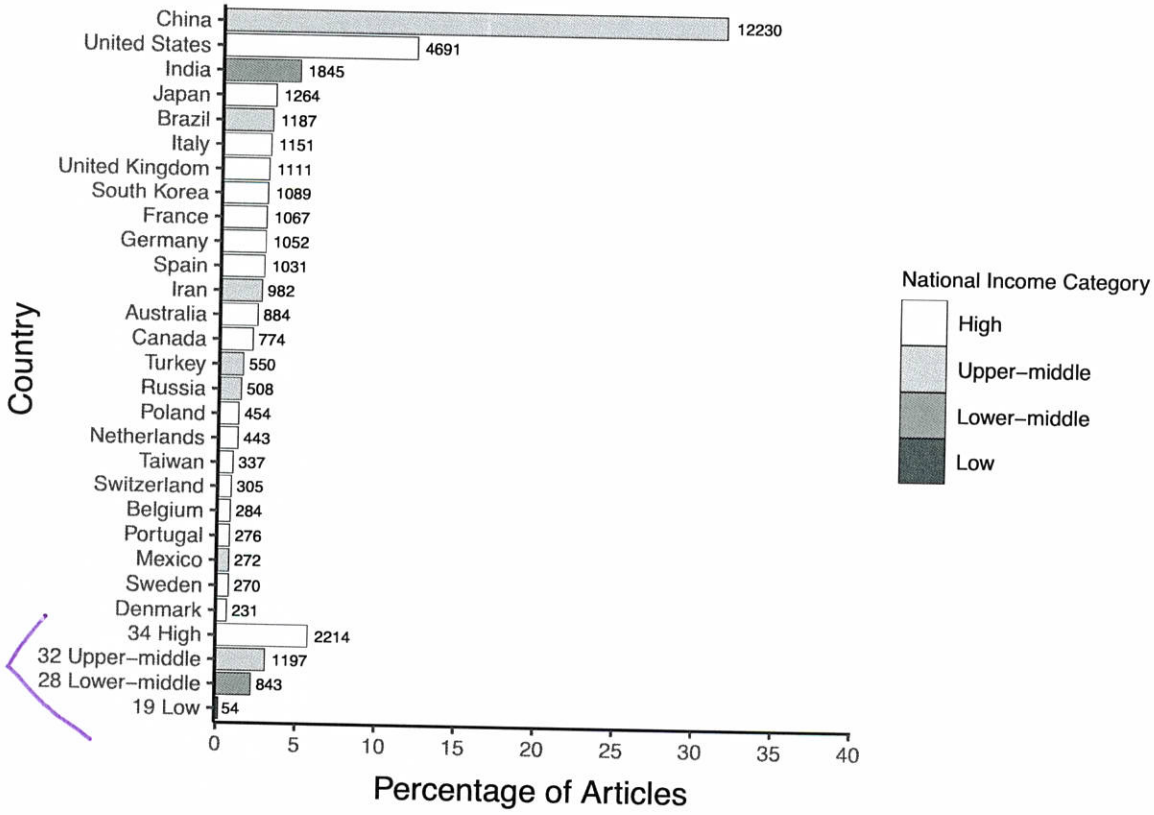

Figure A1. Percentage of lead authors based in different countries. Includes both Parent and Mirror journals. Lead authors include the authors of sole-authored papers and first authors of co-authored papers. Numbers adjacent to bars are the number of articles with lead authors based in that country.

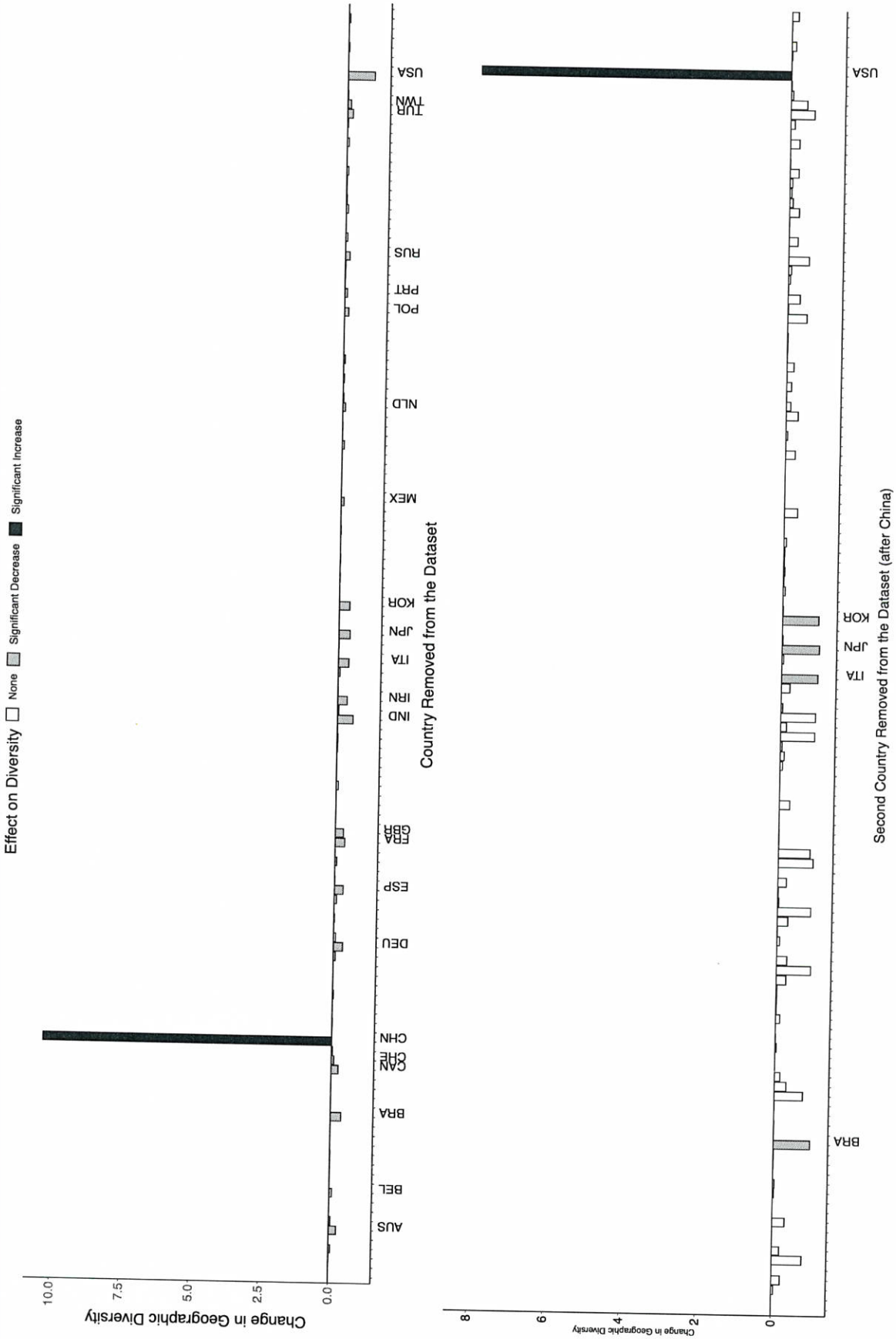

Figure A2. The effect on author geographic diversity of excluding authors from individual countries (B) The effect on author geographic diversity of excluding authors from individual countries after having first removed China.

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## [[1]]
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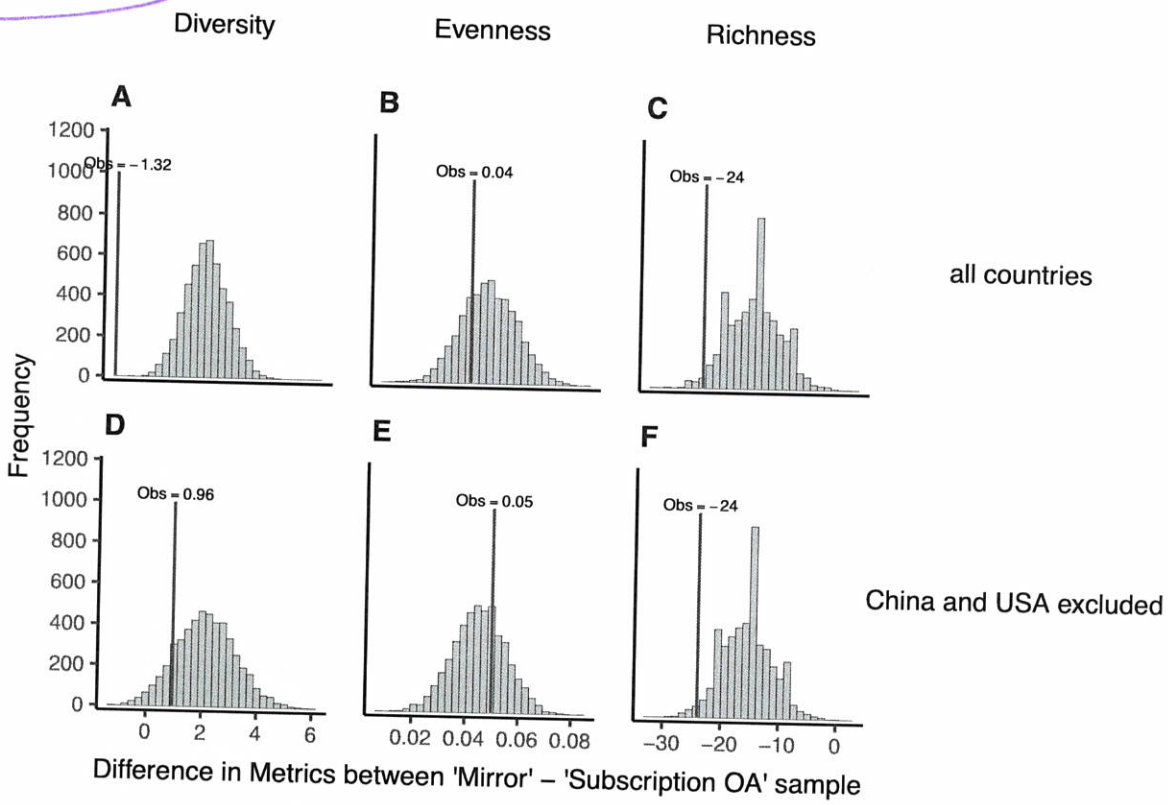

Figure A3. Results of permutation tests comparing author Diversity, Richness, and Evenness of Open Access articles published in Parent and Mirror journals. The red line indicates the observed difference between the two populations, while the bars represent the frequency in 5000 permutations of the difference between two groups identical in size and structure to the observed collections by to which articles were assigned at random by sampling without replacement.

Table A1

Results of permutation tests comparing the difference in diversity and richness of (A) articles in Mirror journals and (B) open access articles in parent journals.

Mirror	Subscription	Obs. Diff.	Metric	Countries	$\hat{P}$
11.97	13.29	-1.32	Diversity	all countries	0*
61.00	85.00	-24.00	Richness	all countries	1.68*
0.75	0.72	0.04	Evenness	all countries	27.14
18.29	17.33	0.96	Diversity	China and USA excluded	13.74
59.00	83.00	-24.00	Richness	China and USA excluded	1.38*
0.81	0.76	0.05	Evenness	China and USA excluded	67.44

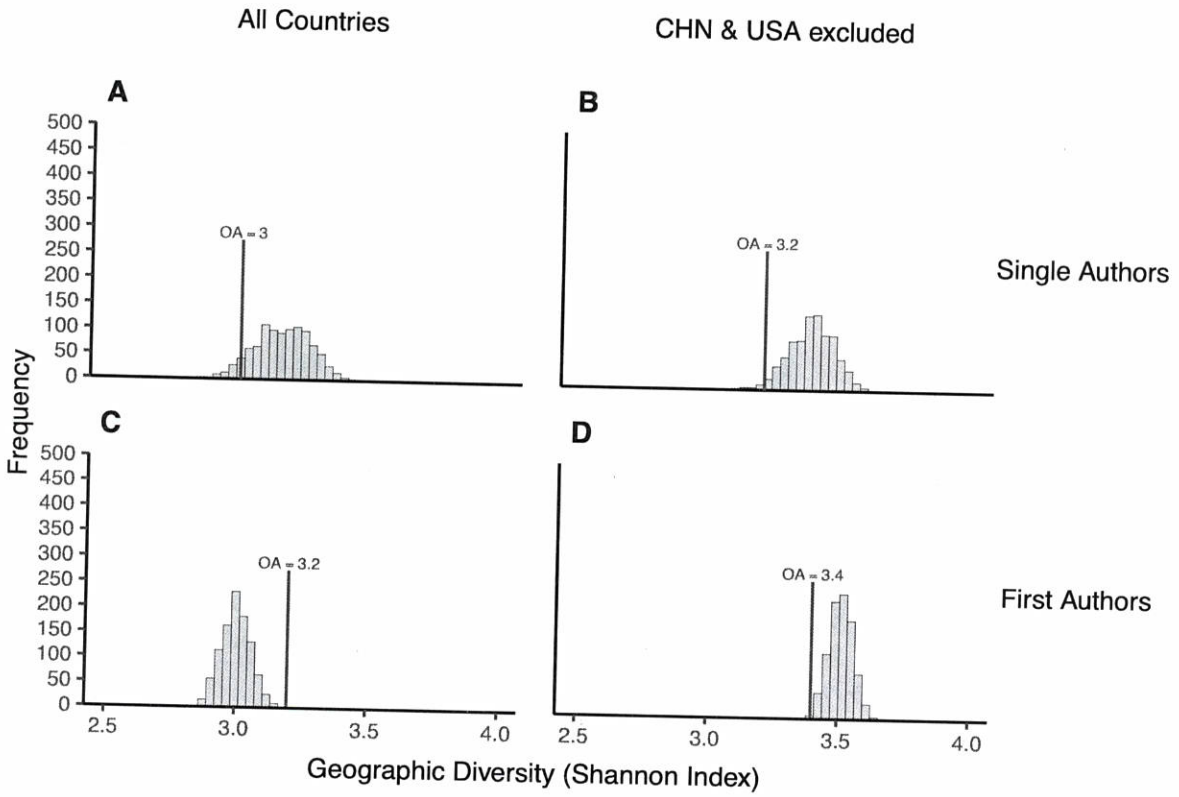

Figure A4. Author Geographic Diversity (calclulated with Shannon's Index) for N = 2794 articles in Mirror journals (solid line) and 1000 identically sized collections generated by selecting an identical number of subscription articles in Parent journals by bootstrapping from the pool of N = 34293 total articles.