1 Article processing charges, the geographic diversity of author communities, and barriers to

2 publication for authors in the Global South

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30 Abstract

31 Many open access (OA) journals require authors pay an article processing charge (APC),

32 which researchers in the Global South often cite as a major financial barrier. This has led to

33 speculation that there will be lower representation of these authors in OA journals charging

34 APCs. We used “Mirror journals” – APC-charging OA versions of subscription "Parent”

35 journals with whom they share editorial boards and standards for acceptance – to investigate

36 the relationship between APCs and the geographic diversity of authors. Most of the >36,000

37 articles we reviewed were published in Parent journals. Although lead authors were based in

38 >140 countries, ~45% were based in either the United States of America (USA) or China.

39 After correcting for differences in sample size, we found no difference between Mirror and

40 Parent journals in the number of countries in which lead authors were based. However, after

41 accounting for the dominance of China and the USA we found that author diversity of

42 Mirror journals was significantly lower than that of Parent journals. Most OA articles were

43 written by authors in high-income countries; no articles in Mirror journals had first authors

44 from low-income countries. Our results are consistent with the hypothesis that APCs are a

45 barrier to OA publication for scientists from the Global South.

46 *Keywords:* Open access, author diversity, geographic

47 diversity, Global South, Mirror journals,

48 Word count: 4602

49 Article processing charges, the geographic diversity of author communities, and barriers to

50 publication for authors in the Global South

## 51 1 Introduction

52 Open Access (i.e., OA) articles can be read without payment or subscription to the

53 journal in which they are published, and the number of OA articles published annually has

54 grown dramatically over the last two decades (Piwowar et al., 2018). In addition to

55 benefiting readers without access to traditional subscription-based journals, open access

56 publishing can also benefit an article’s authors (reviewed in McKiernan et al., 2016; Tennant

57 et al., 2016). For instance, OA articles can garner more online views, have higher download

58 rates, and accrue more citations over time than articles in subscription outlets (Davis, 2011;

59 Eysenbach, 2006; Wang, Liu, Mao, & Fang, 2015). Metrics such as these are increasingly

60 taken into consideration when conducting performance evaluations of scientists, including the

61 tenure and promotion process in academic institutions (Schimanski & Alperin, 2018).

62 Publishing OA articles can therefore play an important role in a scientist’s professional

63 advancement and status (MacLeavy, Harris, & Johnston, 2020; McKiernan et al., 2016). This

64 will be the case regardless of whether the article is in a journal where all articles are open

65 access (i.e., a “Gold OA” journal) or a “Hybrid” journal that publishes both open access

66 articles and articles that are only available to subscribers. However, the professional value of OA is

67 likely to be especially high for Gold OA journals that have other characteristics valued by

68 evaluators: name recognition, high impact factor, perceived prestige, and association with

69 certain academic societies (Gray, 2020; Schimanski & Alperin, 2018).

70 Publication in Gold OA journals is also increasingly required by government agencies

71 and private foundations that fund research (Björk & Solomon, 2014; Pinfield, 2013).

72 Scholars can publish at no expense in most Gold OA journals (Crow, 2009). However, the

73 vast majority of OA articles are published in journals that require authors to pay an ‘article

74 processing charge’ (APC) that helps defray the cost of journal operations (e.g.,Gold OA journals)

75 or offset lost subscription revenue (Hybrid journals) (Crow, 2009; Kozak & Hartley, 2013;

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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 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 South1, 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 waiving or reducing 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 their research 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. 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).

101 Journals” (Harrison, 2019), thereby attracting authors preferring or required to publish in a

102 Gold OA journal. As with most Hybrid journals, there is no cost to authors publishing in

103 the Parent journal unless they want their article to be open access; the APC for doing so is

104 identical to that charged by the corresponding Mirror journal (median = $2600, range =

105 $1318–$3750, Table 1). Mirror and Parent journals are cross-promoted on each others’

106 websites, as are the publishers APC waiver policies.

107 The Parent-Mirror system is an ideal ‘natural experiment’ with which to test for

108 associations between APCs and author diversity. First, it eliminates three of the major

109 factors that have hampered prior comparisons of OA and subscription journals:

110 between-journal differences in aims and scope, potential author base, and the editorial

111 process and criteria with which manuscripts are evaluated. Indeed, several of the journal

112 websites emphasize that articles are processed with neither editors nor referees aware of

113 whether an article was submitted to the Parent or Mirror journal. Furthermore, each

114 Parent-Mirror pair has the same editorial board, which eliminates potential biases resulting

115 from author-editor relationships. Finally, one can compare the authors of articles in the

116 Mirror journal with those of the Open Access and the subscription-only articles in the

117 established Parent journal. This comparison can be used to assess whether any

118 Parent-Mirror differences could actually be due to factors other than APCs that also shape

119 author submission decisions, such as journal impact factor, national incentives, prior

120 experience with the Parent journal, or limited familiarity with Mirror journals.

121 We used data from over 37,000 articles published in 38 Parent journals and their

122 respective Mirrors to investigate the relationship between APCs and the geographic

123 structure of author communities. We test three predictions: First, that the lead authors of

124 OA articles in Mirror journals would be similar in geographic diversity and structure to the

125 authors of OA articles in Parent journals. Second, that the geographic diversity of lead

126 authors in OA articles in both Mirror and Parent journals would be lower than that of

127 subscription-only articles in Parent journals. Third, that any such reductions would be due

128 to OA articles having fewer lead authors from low-income countries. We tested these

129 hypotheses using diversity indices derived from information theory that are commonly used

130 across disciplines for quantifying and comparing the structure of groups (Calver, Bryant, &

131 Wardell-Johnson, 2018; Espin et al., 2017; Magurran, 2004). In doing so we not only provide

132 a robust analysis of the association between APCs and author representation, but also the

133 first comparison of author communities in the Mirror-Parent publishing framework.

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## 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 identified 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 of affiliation is located and assigned the country to its respective World Bank Region2 and Lending Group3 (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* = 1

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*p*

2 *R* 2

*i≠*1 *i*

152 where *R* is the maximum value of Richness, and *pi* is the proportional abundance of

153 type *i* during time interval *t*. Values of *D*2 calculated for different groups are directly

154 comparable; larger values of *D*2 indicate greater diversity, with the maximum potential

155 diversity equal to the highest value of Richness in the group (Magurran, 2004).

156 We began by comparing the geographic diversity of authors publishing in OA Mirror

157 journals with that of authors publishing OA articles in Parent journals (Prediction 1) using

158 permutations tests. We found no difference in the Geographic Diversity of authors of these

159 two groups of OA articles (Table A1, Figure A3).

160 The number of OA articles in both Parent and Mirror journals precluded robust

161 comparisons of Geographic Diversity for journal pairs. We therefore calculated and compared

162 the Geographic Diversity (*D*2) of lead authors at the level of ‘article type’ (i.e., subscription

163 vs. OA). It is important to note, however, that we cannot simply pool the OA and Paywalled (PW)

164 articles from the different journals and compare the resulting Diversity scores of the different

165 groups. This is because there were 12-fold more PW articles than OA articles, and Richness,

166 which is used to calculate (*D*2), increases with sample size. Furthermore, any analyses

167 conducted on a collection of articles drawn from multiple journals would be skewed by

168 patterns in the journals with the most articles. We therefore used abundance-matched

169 bootstrapping (Efron & Tibshirani, 1994) to compare the geographic diversity of the pooled

170 OA articles with that of 1000 different collections of PWarticles. These

171 collections were generated by counting the number of articles published in each OA Mirror,

172 then randomly sampling with replacement an identical number of Paywalled articles from

173 the respective Parent journal (Fox, 2015). To determine if the Geographic Diversity of OA

174 and PW articles were significantly different we calculated *P*ˆ – the proportion of PW

175 collections whose value of *D*2 was below that of the OA collection. A *P*ˆ > 0.975 indicates

176 the Diversity of the OA collection is significantly greater than that of the PW samples; OA

177 Diversity is significantly lower than that of PW samples when *P*ˆ < 0.025. The same

178 procedure was used to compare the proportion of PW and OA articles written by

179 authors in different global regions and national income categories. The analyses above were

180 conducted for two types of lead authors: (1) the authors of single-authored papers, and (2)

181 the first authors of co-authored papers. We analyzed single- and co-authored papers

182 separately because of the potential insights into financial constraints that could emerge from

183 divergent results for these author types: while the APC for a single-authored paper is the

184 responsibility of one person, the APC of a co-authored paper can potentially be divided

185 among – or even paid entirely by – co-authors with access to funding.

186 Simpson’s Index is robust to moderate differences in sampling effort. However, it is

187 sensitive to how equitably samples are distributed between categories (i.e., it is a ‘dominance’

188 or ‘evenness’ index, Magurran, 2004), meaning more dominant categories will have

189 disproportionately greater effects on *D*2. Failure to consider this effect can lead to incorrect

190 inference regarding differences in diversity, especially in cases where dominance is most

191 pronounced. This is because a small number of dominant categories can dramatically lower

192 *D*2 even if the number of remaining categories and their proportional representation are

193 identical. Put another way, dominant categories “suppress” the contributions to diversity of

194 the other categories in a group.

195 Because over 40% of first authors were based in either China or the United States (Fig.

196 A1), we sought to assess if this dominance could be biasing estimates of author diversity. To

197 do so we conducted a series of simulations in which we sequentially removed authors from

198 each country and measured the resulting change in *D*2. China was the only country whose

199 exclusion led to increased diversity, with a relative effect on *D*2 that was 142 times that of

200 any other country (Fig A2). We then excluded all papers with first authors based in China

201 and repeated our simulations. Diversity only increased (8-fold) when excluding articles with

202 first authors based in the USA, with a relative effect on diversity that was 31 times greater

203 than that of any other country (Fig A2). These results indicate that there is a large and

204 negative bias in *D*2 when including authors from the USA and China in analyses. We

205 therefore conducted all analyses both with and without authors from these two countries.

206 We also repeated all analyses with Shannon’s Index, which is somewhat less sensitive to

207 extreme differences in relative frequency than Simpson’s Index. Results for Simpson’s and

208 Shannon’s indices were qualitatively similar (Fig. A2), so we present here only the results for

209 Simpson’s Index.

210 All data analyses were carried out with code written in the R statistical programming

211 language (R Core Team, 2020). We used the **refplitr** (Fournier, Boone, Stevens, & Bruna,

212 2020) and **bibliometrix** (Aria & Cuccurullo, 2017) libraries to process the Web of Science

213 and SCOPUS records (respectively) and georeference lead authors. We used the online

214 **MapAffil** tool (Torvik, 2015) to manually georeference the 141 addresses that these

215 packages were unable to georeference automatically. Richness and Diversity were calculated

216 with the **vegan** library (Oksanen et al., 2019), while **ggplot2** (Wickham et al., 2019) was

217 used for all data visualizations4.

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## 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 in 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.

230 authors from China published 3-times more Paywalled articles than authors from the USA

231 (Figs. 1, 2).

232 **3.1 Geographic Diversity**

233 *First Authors of co-authored articles:* Author geographic diversity as lower for PW

234 than OA articles when all countries were included in the analyses. The pattern was reversed,

235 however, after correcting for the dominance of authors based in the USA and China – author

236 geographic diversity of both Mirror journals and OA articles in Parent journals was

237 significantly lower than that of PW journals (*D*¯ *PW* = 24.52 *±* 1.4 SD, *DMirror* = 17.7,

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238 *DOAinParent* = 16.5; Fig. 3, Table 2). *Sole-authored articles:* The results for sole-authored

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239 articles were more complex. OA articles in Parent journals had significantly lower author

240 diversity than PW articles in Parent journals whether or not China and the USA were

241 included in the analyses (Fig 3). In contrast the values of *D*2 for Mirror journals - while

242 lower than for for PW articles in Parent journals were not significantly different for either

243 the “All Countries” or “China and USA Excluded” comparisons (Fig. 3, Table 2).

## 244 3.2 Global Regions and National Income Categories

245 When correcting for differences in sample size by bootstrapping, we found that OA

246 articles in Mirror journals had significantly more authors from North America and the East

247 Asia / Pacific region than PW articles in Parent journals. They also had significantly fewer

248 authors from Latin American and the Caribbean, the Middle East and North Africa, and

249 Sub-Saharan Africa (Fig. 4, Table 4). Consequently, the authors of articles in Mirror

250 journals were significantly more likely to be based in high-income countries (Fig. 5, Table 5),

251 while authors from middle-income countries were significantly underrepresented. Overall, a

252 nearly identical proportion of Paywalled articles in Parent journals had first authors based in

253 upper-middle and high-income countries (47.3% and 47.5%, respectively). In contrast, an

254 overwhelming majority of articles in Mirror journals were written by first authors based in

255 high-income countries (81%; Fig. A3).

256 The dearth of lead authors from low-income countries was especially notable. None of

257 the 975 articles in Mirror journals had first authors from low-income countries. Only **XX%**

258 of the articles in Parent journals were written by lead authors based in low-income countries;

259 of these the overwhelming majority were subscription-only articles in Parent journals (**N =**

260 **41 of 54**) (Fig. 1B). Across all journal and article types there were **XX** different low-income

261 countries were represented, with **country** as the primary contributor. (Fig. 2B).

262 **4 Discussion**

263 One of the central tenets of open access publishing is that it helps make the scientific

264 community more globally inclusive. This is considered particularly beneficial to scientific

265 communities with limited financial resources, such as those in many countries of the Global

266 South. While this benefit is undisputed, it has been suggested that OA publishing can also

267 have unintended negative consequences for the same communities. Chief among these is that

268 the funding model used by the most widely recognized and prestigious open access journals –

269 a reliance on article processing charges – allows for readers with limited financial resources to

270 access the scientific literature, but also prevents them from contributing to it. We found that

271 author Geographic Diversity was far lower when comparing open access with subscription-only

272 articles, regardless of whether the OA articles were published in Mirror or Parent journals.

273 We also found that an overwhelming majority of open access articles in both Parent and

274 Mirror journals had lead authors based in high-income countries. Of the small number of

275 articles by authors based in low-income countries, most were subscription-only articles in

276 Parent journals. Taken together, these results are consistent with the hypothesis that APCs

277 are a barrier to Open Access publication by scientists from low-income countries located in the Global South.

278 We gained unique insights into the Geographic Diversity and structure of author

279 communities by using an index that accounted for the proportional representation of

280 different countries (i.e., “Evenness”). It is important to remember, however, that all members

281 of a category are treated as functionally equivalent when calculating these indices. This

282 means, for instance, that the number of countries represented in different article or journal

283 categories can be identical even if the specific countries publishing in each are entirely

284 different. Similarly, a more even distribution of authorship reveals nothing about the types

285 of countries whose proportional representation has increased – only that the pattern of

286 national dominance has become less skewed. Although authors of articles in Mirror and

287 Parent journals were based in similar numbers of countries, the specific countries in which

288 they were based were markedly different. Open Access articles had a far higher proportion of

289 authors from North America, Europe/Central Asia, and the East Asia/Pacific region than

290 similarly sized collections of Paywalled articles (Fig. 5). This is in sharp contrast to the

291 Paywalled articles in Parent journals, where proportionately more authors were based in

292 Sub-Saharan Africa, South Asia, the Middle East/North Africa, and Latin America/The

293 Caribbean. Consequently, authorship of OA articles was overwhelmingly concentrated in

294 high-income countries, with proportionately fewer authors from middle-income countries

295 (Fig. 6). For instance, the 15 most ‘productive’ countries of subscription-only articles

296 included 7 in the World Bank’s middle-income categories: China, India, Brazil, Iran, Turkey,

297 Russia, and Mexico (Fig. 2B). In contrast, the top-15 countries of OA articles in Parent and

298 Mirror journals combined included only five middle-income countries: China, India, Brazil,

299 Mexico, and Egypt (Fig. 2A).

300 Perhaps the most surprising result of our study was the dearth of articles by authors

301 from low-income countries (see also Nuñez et al., 2019; Stocks, Seales, Paniagua, Maehr, &

302 Bruna, 2008). Of the more than 37087 we reviewed, only 0.013% (N = 54)**[convert to**

303 **code]** had lead authors based in low-income countries. Most other articles were in Parent

304 journals, all but 2 **[check]** were coauthored articles. Almost half of these articles (44%)

305 had first authors based in Ethiopia, North Korea, Nepal, or Syria; the remainder were based

306 in 19 other countries, mostly in Sub-Saharan Africa **[check these countries]**. While

307 previous studies have documented geographic variation in rates of open access publication,

308 including very low rates in some regions (Iyandemye & Thomas, 2019), these studies all

309 included OA journals in which authors could publish at no cost. The 38 OA journals we

310 reviewed span disciplines from veterinary medicine to nutrition to waste management (Table

311 1); that there were zero papers with lead-authors from low-income countries, including from

312 regions previously shown to have high rates of OA publication, further underscores the

313 conclusion that authors in low-income countries are detrimentally affected by the financial

314 burden of APCs. Previous research on author attitudes toward OA publishing has identified

315 APCs as a barrier to publication, especially for independent researchers, students, and those at

316 institutions focusing on undergraduate education (Coonin & Younce, 2009; Dallmeier-Tiessen

317 et al., 2011; Warlick & Vaughan, 2007). We provide some of the strongest evidence to date

318 that this holds true for researchers in the Global South as well (Appel, Albagli, Appel, &

319 Albagli, 2019; Ezema & Onyancha, 2017; Ncayiyana, 2005). Although it is conceivable that

320 the differences we observed are due to many of our focal journals having above average

321 APCs (Solomon & Björk, 2012b), we believe this is unlikely to be the cause. Authors in

322 low-income countries are far more likely to use personal funds to pay APCs (Solomon &

323 Björk, 2012a), and for many, even the average APC of $904 would consume a large fraction

324 of their research budget (Ciocca & Delgado, 2017; Matheka et al., 2014; Wingfield & Millar,

325 2019), salary (Peterson, Emmett, & Greenberg, 2013), or student stipend (Table 3). Funds

326 to defray publication costs are clearly available to some scientists in some of these countries

327 (Pavan & Barbosa, 2018, Figs. 1 & 2); therefore, the most likely explanation for the observed

328 results is that authors are actively choosing to publish at no cost in the PW journal instead

329 of paying to publish in the OA Mirror (Ciocca & Delgado, 2017).

330 The lack of OA articles by authors based in low-income countries is particularly

331 surprising given that most of these countries are eligible for waivers of APCs under the

332 Elsevier’s “Research4Life” program (Table A1). We suggest there are at least four potential

333 explanations for this. The first is that publisher policies for waiving APCs can be quite

334 restrictive. For instance, the publisher of the OA Mirror journals included in our review will only

335 waive APCs in cases where every co-author of an article is based in a country that is

336 waiver-eligible (Elsevier, 2020). Many of the articles in our dataset with first authors based

337 in low-income countries had international collaborators in locations that rendered the

338 articles ineligible for discounted or free publication (see also Gray, 2020). Second, it may be

339 that authors were unaware waivers existed or that journal or publisher staff failed to

340 recognize their eligibility and offer to transfer their submission to the OA Mirror (Lawson,

341 2015). Third, authors may have been aware of the option to publish in Mirror journals at no

342 expense, but nevertheless opted for publishing in the Parent outlets – perhaps because they

343 view these as more prestigious (Ellers, Crowther, & Harvey, 2017). Finally, even large

344 discounts on APCs are unlikely to be sufficient for many authors (Iyandemye & Thomas,

345 2019). This is almost certainly true for authors in countries that are bizarrely offered only

346 partial discounts (e.g., Honduras, Guatemala) despite socioeconomic conditions that are

347 similar to those in nearby countries where authors can publish OA at no expense (e.g.,

348 Nicaragua, Table A1). In absolute terms, however, the minimal benefit of partial waivers

349 may be most pronounced for authors in middle income countries – especially when they

350 engage in productive collaborate with scientists based in middle-income countries such as

351 Brazil, Mexico, South Africa, and Malaysia (Smith, Weinberger, Bruna, & Allesina, 2014)

352 that are ineligible for waivers despite challenging economic conditions (Ciocca & Delgado,

353 2017). Regardless of the mechanism, our results suggest that waiver programs designed to

354 increase the representation of scientists from the Global South in the OA literature by

355 reducing APCs have at best failed to do so, and at worst have had the opposite effect. Finally, our

356 results also suggest there are some important differences in the way authors perceive Parent

357 and Mirror journals. That there are some OA articles by authors from low-income countries

358 in Parent journals but none in Mirror journals suggests a clear preference for more

359 established titles. The same appears to be true for authors in the high- and middle-income

360 countries where OA publishing is well-established - authors in these countries publish more

361 OA papers in Mirror journals than their respective Parents (Fig 6). This skew is also notable

362 given that Gold-OA publication is increasingly required by many of funders in some of these

363 countries (e.g., the UK), which has led to increased marketing efforts by Elsevier promoting

364 Mirror journals. Finally, the results suggest authors in China and the USA either remain

365 wary of OA publication or do not find the incentives for publishing OA particularly

366 compelling. When these authors have opted for OA, the clearly prefer established Parent

367 journals over the recently established Mirrors.

## 368 4.1 Caveats and Future Directions

369 Inference in bibliometric studies must be drawn with care, as patterns such as those we

370 documented are the result of a complex combination of pre-submission decisions by authors

371 and post-submission decisions by editors. Comparing OA articles published in Mirror

372 journals to those published in Parent journals allows us to control for many of the factors

373 that shape these decisions. Most notably, the journals in a Mirror-Parentpair have identical

374 editorial boards, editorial philosophy, and publication priorities. While any implicit biases

375 held by editors against authors from particular countries would undoubtedly reduce the

376 overall representation of these countries in the literature, the reduction would be independent

377 of the journal access category. As such, we believe our results reflect the outcome of

378 pre-submission decisions by authors and are consistent with APCs being a central

379 underlying mechanism influencing such decisions (Ciocca & Delgado, 2017; Solomon & Björk, 2012a). Our results

380 also suggest several promising directions for future research. The first is to investigate why it

381 appears scientists in some middle- and low-income countries, especially China and Brazil,

382 overwhelmingly prefer to publish in subscription journals despite the apparent availability of

383 funds to defray APCs. These academic communities might consider open access mirrors to

384 be of lower quality, regardless of their affiliation with a known academic society, publisher, or

385 connection to an established subscription journal (Editage, 2018). Alternatively, authors may

386 be hesitant to consider them as outlets for their work because they do not yet have impact

387 factors or other metrics used by their institutions in program evaluation (Appel, Albagli,

388 Appel, & Albagli, 2019; Pavan & Barbosa, 2018; Xu et al., 2020). Second, our results suggest

389 there is a need for research on how to make waiver programs more effective, with particular

390 emphasis on reducing financial barriers to OA publication for authors in both low- and middle-income

391 countries. Answers to these questions will help editors, publishers, and the broader scientific

392 community develop strategies to ensure prestigious open access journals are truly accessible

393 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).*

Parent Journal Mirror Journal

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Title 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 |
| Biochimie1 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 Engineering2 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.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| OA Source Metric Author | OA | All Countries  Parent PW (mean ± SD) | *P*ˆ | OA | Without China & USA  Parent PW (mean ± SD) | *P*ˆ |
| 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 Mexico India  Indonesia | CNPq1 CONACYT2 SERB3  RISTEKDIKTI4 | MS/MA  PhD MS/MA  PhD PhD6 PhD7  MS/MA | 294  431  588  783  747  978  195 |

South Africa NRF5 MS/MA 670

PhD 687

1 <http://cnpq.br/apresentacao13/>

2 https://[www.conacyt.gob.mx/index.php/becas-y-posgrados/becas-nacionales](http://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](http://www.nrf.ac.za/)

6 Min. value, Prime Minister’s Doctoral Fellowship

7 Max. value, Prime Minister’s Doctoral Fellowship

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 *P*ˆ

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\*

* 1. **Mirror Journals**

United States

48

17

16

14

12

10

7

6

6

5

4

4

4

4

3

31

6

5

Japan United Kingdom Netherlands

China Germany France Canada India Spain Australia Brazil Italy

Country

Switzerland Belgium 14 High

6 Upper−middle

3 Lower−middle

0 5 10 15 20 25 30 35 40

* 1. **Parent Journals (Open Access)**

United States United Kingdom Netherlands

8

4

2

2

1

1

1

1

1

1

1

1

1

1

1

1

Income Category

High

Upper−middle Lower−middle Low

Sweden Australia Austria France Germany

Country

|  |
| --- |
|  |
|  |
|  |
|  |

India Israel Japan Norway

Saudi Arabia

Spain Switzerland

1 High

0 5 10 15 20 25 30 35 40

* 1. **Parent Journals (Subscription)**

114

106

52

44

43

32

31

28

25

24

23

20

19

18

16

135

64

22

2

United States

China Turkey India Japan

United Kingdom

France Iran Germany South Korea

Country

Italy Sweden Russia Poland Australia 29 High

19 Upper−middle

9 Lower−middle

2 Low

0 5 10

15 20 25 30 35 40

Percentage of Articles

*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.

1. **Mirror Journals**

United States United Kingdom

173

78

52

44

38

37

30

30

27

23

22

21

19

18

17

90

35

13

China France Netherlands Germany

Italy Japan Canada India Brazil Sweden Spain Australia

Country

Switzerland

21 High

14 Upper−middle

9 Lower−middle

0 5 10 15 20 25 30 35 40

1. **Parent Journals (Open Access)**

United States

331

228

208

161

74

72

65

59

53

49

49

46

46

37

37

Income Category

High Upper−middle Lower−middle Low

200

115

48

13

China United Kingdom Netherlands Germany Canada

|  |
| --- |
|  |
|  |
|  |
|  |

Spain Japan Italy France India Sweden

Country

Switzerland Australia Belgium 24 High

19 Upper−middle

17 Lower−middle

10 Low

0 5 10 15 20 25 30 35 40

1. **Parent Journals (Subscription)**

11832

4017

1722

1114

1109

1041

1020

935

934

925

905

808

773

655

489

3999

1819

755

39

China United States

India Japan Brazil Italy

South Korea

Country

France Iran Spain Germany Australia

United Kingdom

Canada Turkey 41 High

33 Upper−middle

27 Lower−middle

16 Low

0 5 10

15 20 25 30

Percentage of Articles

35 40

*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.

All Countries CHN & USA excluded

**A**

600

Mirror

Parent

500

400

300

200

100

Frequency

0

**C**

600

Mirror

Parent

500

400

300

200

100

0

**B**

Single Authors

Mirror

Parent

**D**

Mirror Parent

First Authors

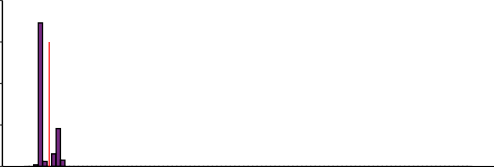
5 10 15 20 25 30 5 10 15 20 25 30

Geographic Diversity

*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).

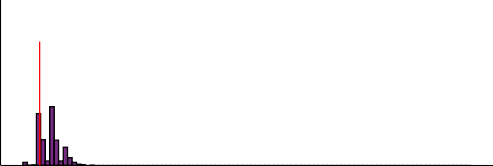
Single Authors First Authors

800



**A**

OA



**B**

OA

600

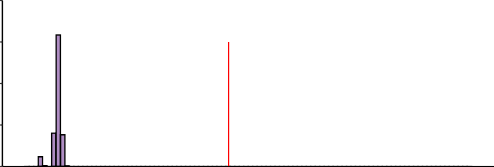
400

200

South Asia

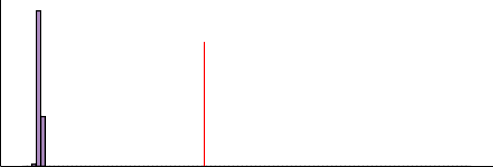
0

800



**C**

OA



**D**

OA

600

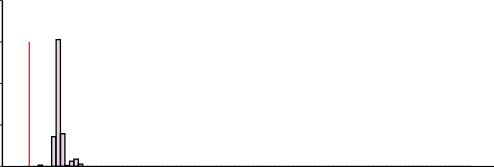
400

200

North America

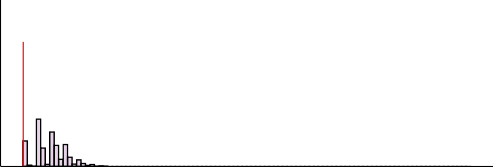
0

800



**E**

OA



**F**

OA

600

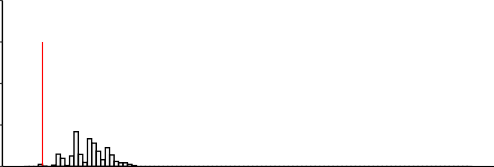
400

200

Sub−Saharan Africa

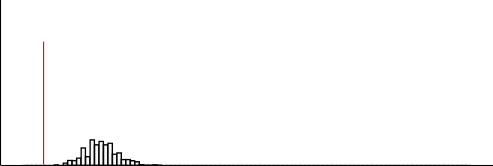
0

800



**G**

OA



**H**

OA

600

Frequency

400

200

Latin America & Caribbean

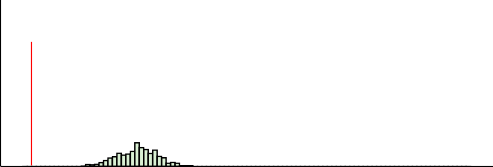
0

800



**I**

OA



**J**

OA

600

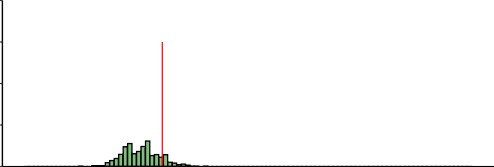
400

200

Middle East & North Africa

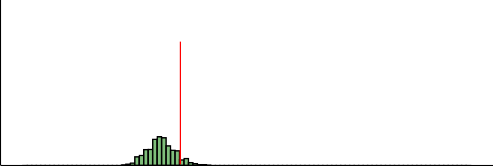
0

800



**K**

OA



**L**

OA

600

400

200

East Asia & Pacific

0

800



**M**

OA



**N**

OA

600

400

200

0

0 20 40

60 0 20 40

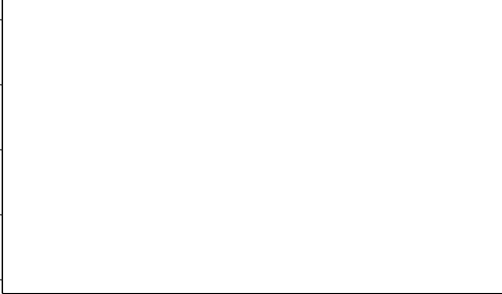
Europe & Central Asia

Percentage of authors in each region

*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).

Single Authors First Authors

800



**A**



**B**

OA

600

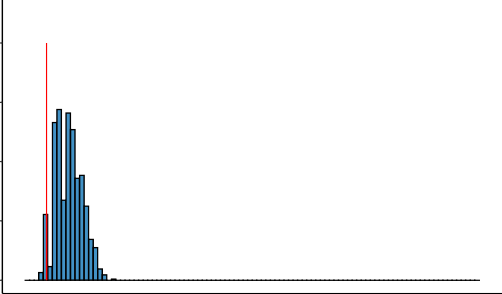
400

Low Income

200

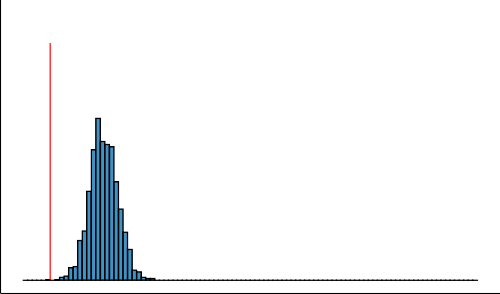
0

400



**C**

OA



**D**OA

300

Lower−middle

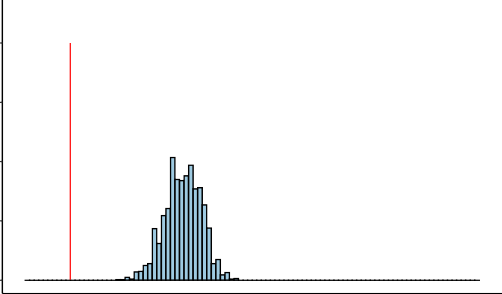
200 Income

100

0

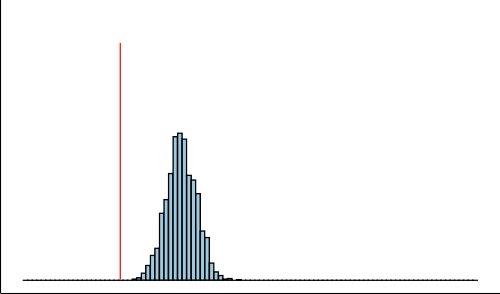
Frequency

400



**E**

OA



**F**

OA

300

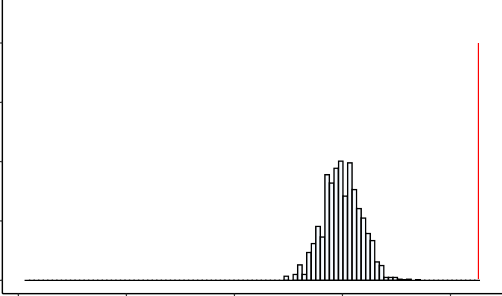
Upper−middle

200 Income

100

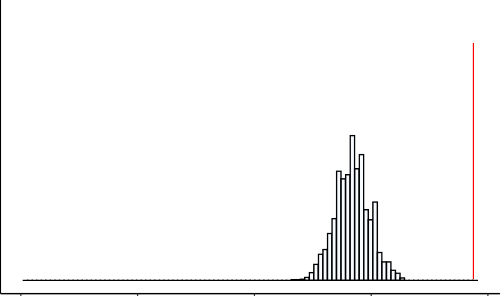
0

400



**G**

OA



**H**

OA

300

High

200 Income

100

0

0 20 40 60 80

0 20 40 60 80

Percentage of authors in each World Bank Lending Group

*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).

340 



USA

CHN

GBR

NLD

DEU

ESP CAN JPN

National Income Category

High Upper−middle Lower−middle

CHE

ITA

FRA

BEL IND

SWE BRA

KOR AUS NOR

AUT

DNK

320

300

280

260

240

No. of OA articles in Subscription Journals

220

200

180

160

140

120

100

80

60

40

20

00 20 40 60 80 100 120 140 160 180 200 220 240

No. of articles in Mirror Journals

*Figure 6* . For the 15 countries publishing the most open access (OA) articles, the number of OA articles published in Mirror journals vs. Parent kournals. 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

China United States

India Japan Brazil Italy

United Kingdom South Korea

France Germany

Spain Iran Australia Canada Turkey Russia Poland Netherlands

Country

Taiwan Switzerland

Belgium Portugal Mexico Sweden Denmark 34 High

32 Upper−middle

28 Lower−middle

19 Low

0 5 10 15 20 25 30

12230

4691

1845

1264

1187

1151

1111

1089

1067

1052

1031

982

884

774

550

508

454

443

337

305

284

276

272

270

231

2214

1197

843

54

Percentage of Articles

35 40

National Income Category High

Upper−middle Lower−middle Low

|  |
| --- |
|  |
|  |
|  |
|  |

*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.

Change in Geographic Diversity

10.0

7.5

5.0

2.5

0.0

8

6

4

2

0

Change in Geographic Diversity

AUS BEL

*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.

BRA

ITA JPN KOR

Second Country Removed from the Dataset (after China)

USA

APCS & AUTHOR DIVERSITY

36

BRA

CAN CHE

CHN

DEU

ESP

Effect on Diversity

FRA GBR

IND IRN

None

Country Removed from the Dataset

ITA JPN KOR

Significant Decrease

MEX

Significant Increase

NLD

POL PRT

RUS

TUR TWN

USA

583 ## [[1]]

Diversity Evenness Richness

**A B C**

all countries



1200

1000Obs   1.32

800

600

400

200

0



Obs  0.04



Obs   24

**D E**

Frequency

1200



Obs  0.96



Obs  0.05

1000

800

600

400

200

0

**F**

China and USA excluded



Obs   24

0 2 4 6 0.02 0.04 0.06 0.08 −30 −20 −10 0

Difference in Metrics between 'Mirror' − 'Subscription OA' sample

*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 *P*ˆ

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

All Countries CHN & USA excluded

**A**

500

OA  3

450

400

350

300

250

200

150

100

50

Frequency

0

**C**

500

OA  3.2

450

400

350

300

250

200

150

100

50

0

**B**

Single Authors

OA  3.2

**D**

OA  3.4

First Authors

2.5 3.0 3.5 4.0 2.5 3.0 3.5 4.0

Geographic Diversity (Shannon Index)

*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.

All Countries CHN & USA excluded

**A**

350

OA  39

300

250

200

150

100

50

Frequency

0

**C**

350

OA  94

300

250

200

150

100

50

0

**B**

Single Authors

OA  37

**D**

OA  92

First Authors

30 40 50 60 70 80 90 30 40 50 60 70 80 90

Geographic Richness (R)

*Figure A5* . Author Geographic Richness for N = 2794 Open Access articles (red bar) and 1000 identically sized collections of Paywalled articles selected by bootstrapping from a pool of 34293 articles. The black line indicates the mean value for the 1000 bootstrap collections.

100

90

80

70

60

50

40

30

20

10

0

1. **Open Access Articles − Mirror**

100

90

Articles (%)

80

70

60

50

40

30

20

10

0

1. **Open Access Articles − Parent**

100

**(C) Paywalled Articles − Parent**

90

80

70

60

50

40

30

20

10

0

High Upper middle Lower middle Low

World Bank Lending Group (all lead authors)

*Figure A6* . Proportion of lead authors based in different World Bank Lending Groups for

(A) N = 2794 articles in Mirror journals and (B) N = 34293 subscription articles in Parent journals.

Table A2

APCS & AUTHOR DIVERSITY

41

*Countries eligible for APC waivers through Elsevier’s ’Research4Life’ program by World Bank Global Region and Income Group.*

|  |  |  |
| --- | --- | --- |
| Region Income Group A - 100% | B - 50% | no waiver |
| South Asia Low income Afghanistan, Nepal | - | - |
| Middle income Bangladesh, Bhutan | Maldives, Pakistan, Sri Lanka | India |
| Sub-Saharan Africa Low income Benin, Burkina Faso, Burundi | - | - |
| Central African Republic, Chad, Dem. Repub. Congo, Eritrea | - | - |
| Ethiopia, Gambia, Guinea, Guinea-Bissau | - | - |
| Liberia, Madagascar, Malawi, Mali | - | - |
| Mozambique, Niger, Rwanda, Sierra Leone | - | - |
| Somalia, South Sudan, Tanzania, Togo | - | - |
| Uganda | - | - |
| Middle income Angola, Cabo Verde, Cameroon | Botswana, Gabon, Mauritius | South Africa |
| Comoros, Congo, Equatorial Guinea, Eswatini | Namibia, Nigeria | - |
| Ghana, Ivory Coast, Kenya, Lesotho | - | - |
| Mauritania, Sao Tome & Principe, Senegal, Sudan | - | - |
| Zambia, Zimbabwe | - | - |
| High income - | Seychelles | - |
| Latin America & Caribbean Low income Haiti | - | - |
| Middle income Belize, Nicaragua | Bolivia, Colombia, Cuba | Argentina, Brazil, Costa Rica |
| - | Dominica, Ecuador, El Salvador, Grenada | Dominican Republic, Mexico |
| - | Guatemala, Guyana, Honduras, Jamaica | - |
| - | Paraguay, Peru, Saint Lucia, Saint Vincent & the Grenadines | - |
| - | Suriname, Venezuela | - |
| High income - | Antigua & Barbuda, Saint Kitts & Nevis | Aruba, Bahamas, Barbados |
| - | - | British Virgin Islands, Cayman Islands, Chile, Curaçao |
| - | - | Panama, Puerto Rico, Saint Martin (FRA), Sint Maarten |
| - | - | Trinidad & Tobago, Turks & Caicos Islands, U.S. Virgin Islands, Uruguay |
| Middle East & North Africa Low income Syrian Arab Republic, Yemen | - | - |
| Middle income Djibouti | Algeria, Egypt, Iraq | Iran, Lebanon |
| - | Jordan, Libya, Morocco, Tunisia | - |
| - | West Bank & Gaza Strip | - |
| High income - | - | Bahrain, Israel, Kuwait |
| - | - | Malta, Oman, Qatar, Saudi Arabia |
| - | - | United Arab Emirates |
| E. Asia & Pacific Low income Democratic People’s Republic Korea | - | - |
| Middle income Cambodia, Fed. States Micronesia, Kiribati | Fiji, Mongolia, Nauru | American Samoa, China, Indonesia |
| Laos, Marshall Islands, Myanmar, Papua New Guinea | Vietnam | Malaysia, Philippines, Thailand |
| Samoa, Solomon Islands, Timor-Leste, Tonga | - | - |
| Tuvalu, Vanuatu | - | - |
| High income - | Palau | Australia, Brunei, French Polynesia |
| - | - | Guam, Hong Kong, Japan, Macao |
| - | - | N. Mariana Islands, New Caledonia, New Zealand, Singapore |
| - | - | South Korea, Taiwan |
| Tokelau | Cook Islands, Niue | - |
| Europe & Central Asia Low income Tajikistan | - | - |
| Middle income Kyrgyzstan, Republic Moldova | Albania, Armenia, Azerbaijan | Bulgaria, Kazakhstan, Romania |
| - | Belarus, Bosnia & Herzegovina, Georgia, Kosovo | Russia, Turkey, Turkmenistan |
| - | Montenegro, North Macedonia, Serbia, Ukraine | - |
| - | Uzbekistan | - |
| High income - | - | Andorra, Austria, Belgium |
| - | - | Croatia, Cyprus, Czechia, Denmark |
| - | - | Estonia, Faroe Islands, Finland, France |
| - | - | Germany, Gibraltar, Greece, Greenland |
| - | - | Hungary, Iceland, Ireland, Isle Man |
| - | - | Italy, Latvia, Liechtenstein, Lithuania |
| - | - | - |
| - | Saint Helena | - |
| North America High income - | - | Bermuda, Canada, United States |