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Assessing the size of the affordability problem in scholarly publishing

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Abstract

For many decades, the hyperinflation of subscription prices for scholarly journals have concerned scholarly institutions. After years of fruitless efforts to solve this “serials crisis”, open access has been proposed as the latest potential solution. However, also the prices for open access publishing are high and are rising well beyond inflation. What has been missing from the public discussion so far is a quantitative approach to determine the actual costs of efficiently publishing a scholarly article using state-of-the-art technologies, such that informed decisions can be made as to appropriate price levels. Here we provide a granular, step-by-step calculation of the costs associated with publishing primary research articles, from submission, through peer-review, to publication, indexing and archiving. We find that these costs range from less than US\$200 per article in modern, large scale publishing platforms using post-publication peer-review, to about US\$1,000 per article in prestigious journals with rejection rates exceeding 90%. The publication costs for a representative scholarly article today come to lie at around US\$400. We discuss the additional non-publication items that make up the difference between publication costs and final price.

1 Introduction

2 The affordability problem of scholarly publish-
3 ing, i.e., the hyperinflationary price increases with
4 stagnating library budgets, has been discussed for
5 decades (see, e.g., Chan 2004; Harnad et al. 2004;
6 Douglas 1990; Fisher 2008; Houghton 2001;
7 Tananbaum 2003; Rose-Wiles 2011). In recent years,
8 perhaps precipitated by some so-called ‘gold’ open ac-
9 cess (OA) journals charging article-processing charges
10 (APCs; fees usually charged to authors or their institu-
11 tions upon acceptance for publishing an article and
12 making it openly available), the *average cost of an arti-*
13 *cle* has emerged as a useful measure with which to
14 compare different business models. However, most
15 authors refer to the *prices* charged by the publisher,
16 not the actual *cost* to the publisher (e.g., Van Noorden
17 2013; Schimmer et al. 2015; Odlyzko 2013; Johnson et
18 al. 2018). One consequence of this mis-attribution is a
19 potential overestimation of the actual costs of schol-
20 arly publishing due to the inclusion of the business
21 models and pricing strategies of publishers into the
22 calculation. To close this gap, here we provide a bot-
23 tom-up calculation of the cost of efforts and services
24 which are required to achieve a certain service level in
25 order to publish an academic journal article. We com-
26 pare our *cost* estimate with the current *pricing*
27 schemes of publishers.

28 Traditionally, access to scholarly publications
29 has been provided through a subscription model.
30 Non-disclosure agreements, commonly used by sub-
31 scription publishers today (with the explicit intent to
32 increase prices (Tempest 2013)), make it difficult to cal-
33 culate per-article prices at the level of journals, pub-
34 lishers or countries. However, it is known how many
35 scholarly articles are being published every year on a
36 world-wide basis (2.4 million in 2017, (White 2019))
37 and there are converging estimates on the subscrip-
38 tion revenue spent world-wide each year (approx.
39 US\$10 billion; Van Noorden 2013; Schimmer et al.
40 2015; Odlyzko 2013; Johnson et al. 2018). Dividing
41 these two figures leads to a widely agreed per-article
42 price of approx. US\$5,000 paid largely by libraries for
43 the subscription system (Johnson et al. 2018). Both fig-
44 ures are reportedly slightly higher today, but the final
45 per article price is relatively unchanged and still re-
46 markably close to a long-standing US\$4,000/article es-
47 timate (Odlyzko 1995; Johnson et al. 2018). Taken to-
48 gether, with both the revenue and the publication vol-
49 ume increasing over the last decades, the per-article
50 price of the subscription system has remained rela-
51 tively constant between US\$4,000-5,000, further vali-
52 dating the value of this measure.

53 While most OA journals do not charge APCs (or
54 other author-facing fees, such as submission fees) and
55 instead finance their services via alternative routes
56 (71% of journals listed in the Directory of Open Access

57 Journals, DOAJ), most OA articles are being published
58 in the minority of journals which do charge APCs (58%,
59 Crawford 2019). So far, in contrast to subscription
60 prices, APCs are commonly not covered by non-disclo-
61 sure agreements. On the contrary, most journals pub-
62 licly list their APCs. Moreover, in those cases where
63 APCs are paid by research organizations, universities
64 or academic libraries on behalf of their authors, there
65 are data available on a more granular basis compared
66 to the subscription-based business model. For in-
67 stance, Jahn and Tullney calculated from APCs for
68 7,417 journals which have been paid by 30 German ac-
69 ademic libraries between 2005 and 2015 an average
70 APC of 1,298€ (~US\$1,470)(Jahn & Tullney 2016). In
71 contrast, Schimmer et al. (2015) project an average
72 APC of 2,000€ (~US\$2,260) for their scenario of transi-
73 tioning to a full OA system. In a sample covering the
74 USA and Canada, APCs averaged US\$1,775 (Solomon
75 & Björk 2016). Confirming these numbers, Morrison
76 (2018a) finds that the most common APC in her sam-
77 ple is US\$1,780. In the UK, JISC reports average APCs
78 around 1,700£ (~US\$2,240)(Shamash 2017). Covering
79 all DOAJ-listed journals, Crawford finds an average
80 APC paid of US\$1,569 (Crawford 2019). Interestingly,
81 this year, the German DEAL consortium agreed to pay
82 2,750€ (~US\$3,110) per article in their “publish & read”
83 contract with the publisher Wiley (Haufe 2019). Thus,
84 the prices incurred vary from zero to several thou-

85 sands of \$/£/€, an additional reason why these num-
86 bers - while accurate - are not useful for a reliable cal-
87 culation of what the scholarly publishing of public re-
88 search could or should cost.

89 From the figures available, it is straightforward
90 to hypothesize that publishers, by and large, deter-
91 mine their price structure according to what they esti-
92 mate the market to be able to carry, i.e., with a value-
93 based (or prestige) pricing strategy in a market with
94 status consumption (Goldsmith et al. 2010; Kumcu &
95 McClure 2003). Both the subscription approach and
96 the APC approach share the same basic property,
97 which uncouples the price charged from the costs in-
98 curred: non-substitutability. In the subscription sys-
99 tem, due to rules such as the Ingelfinger rule (Marshall
100 1998; Angell & Kassirer 1991) that prevent duplicate
101 publications, each article can be found at only one
102 journal of one publisher exclusively. Hence, due to this
103 lack of competition, subscription pricing need not be
104 coupled to publication costs, but purely to reader de-
105 mand. Analogously, the more than 34,000 scholarly
106 journals are not only differentiated by the areas of
107 scholarship they serve, they are also stratified in a
108 ranking system where no two journals share the same
109 position, conveying prestige and status to authors.
110 Thus, as duplicate publications are still prevented in
111 OA as in subscription journals, the number of journals
112 in a particular field and prestige stratum effectively
113 equals one. The APC-OA 'market' hence suffers from

114 analogous non-substitutability problems as the sub-
115 scription market, leading to market failure and hyper-
116 inflation also there (Crawford 2019; Morrison 2018a;
117 Shamash 2017; Khoo 2019). Corroborating these ob-
118 servations are data that also APCs fluctuate with au-
119 thor demand rather than with costs and that authors
120 appear to be price-insensitive (Schönfelder 2018; An-
121 drew 2012; Khoo 2019). In fact, at least two publishers
122 have publicly stated that their pricing was driven not
123 by costs, but by market and competitor analysis
124 (Poynder 2015; Morrison 2018b). Thus, in both sys-
125 tems, monopolistic situations have arisen that let de-
126 mand, prestige and purchasing power, rather than
127 cost drive the prices. The non-substitutability in these
128 markets appears to be a major contributing factor
129 leading to value-based pricing. This argument entails
130 that in order to arrive at a truly competitive market
131 where the main driver for price is cost (i.e., promoting
132 a cost-plus pricing strategy), the goods in this market
133 need to be substitutable. As scholarly articles are writ-
134 ten and reviewed by the scholars themselves, the
135 goods in this market are publishing services.

136 The editorial, reviewing, processing, production
137 and publication workflows do not differ with regard to
138 the way they are paid, i.e., via subscriptions, APCs or
139 other modes of payment. For example, so-called hy-
140 brid journals derive their revenue simultaneously
141 from APCs and from subscription fees. Whereas this
142 business practice, to charge both parties, libraries and

143 authors of one and the same journal, has been criti-
144 cized as “double-dipping” (Mittermaier 2015), it simul-
145 taneously proves that editorial workflows and produc-
146 tion service levels must be identical for both business
147 models. Such internal workflows and service levels are
148 usually set by industry standards and the policy of the
149 publisher. Consequently, when calculating the cost of
150 publishing a scholarly article, to arrive at a cost-plus
151 pricing scheme, besides fixed costs, we only have to
152 consider the workflow and associated services, ac-
153 cording to current practice.

154 In this article, we list the various steps and pro-
155 cedures for a representative publishing workflow ac-
156 cording to current industry standards. Each step in-
157 curs a cost which can be determined by analyzing the
158 market rates for each service or procedure. These
159 costs comprise the direct costs. We also add several
160 indirect (or fixed) cost items which do not accrue on a
161 per article basis. The final per-article costs are then
162 specified as a range depending on the number of arti-
163 cles published and the service level desired.

164 Methodology

165 To arrive at a meaningful figure denoting how
166 much the publication of an article does *costs* on aver-
167 age, it is necessary to arrive at the exact cost for each
168 step in the processing workflow of a manuscript being
169 submitted for publication. These direct or variable

170 costs then have to be combined with the indirect or
171 fixed costs of running a publishing enterprise, such as
172 staff costs, real estate and energy costs, etc. The former
173 requires granular insight and expertise about the
174 different service levels for the entire publishing workflow.
175 The latter is commonly calculated as staff overhead.
176 In this work, we have therefore calculated the
177 cost for each step in the standard publication workflow
178 under consideration of both fixed and variable
179 costs. Both external and internal expenses have been
180 taken into account as well as overhead costs to cover
181 fixed non-direct company costs of the publishing venture.
182

183 **Direct or variable costs**

184 Expenses and fees for each individual service
185 have been arrived at from two main sources. Some
186 standard services have been taken from openly available
187 price lists (Table 1).

188

189

Service Provider	Services	Permalink to fee page
CLOCKSS	Long-term preservation	https://perma.cc/2SQ2-VQUJ
CrossRef	DOI	https://perma.cc/N7BY-AJC3
Scholastica	Peer-review, publishing, type-setting	https://perma.cc/Z3DS-EZUW
Akron Aps	Peer-review management	https://perma.cc/U8J5-JS4E

190 **Table 1:** Publishing services and their fees.

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Second, we requested quotes from vendors without publicly available fees, or turned to other sources (ECAT 2009).. For services such as manuscript submission and peer review management systems we considered vendors such as Manuscript Central (Clarivate) and Editorial Manager (ARIES).

198

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Other costs such as internal staff costs (including overhead, EU/US standard) were estimated taking into account not only current market costs we have requested ourselves, but also numbers from major publishing houses (MDPI, Wiley, Springer, DeGruyter, Frontiers, Ubiquity, SciELO, Open Library of the Humanities). While some of these publishers have made

205 their costs public (Table 2), others have either pro-
206 vided their numbers under the condition of confiden-
207 tiality or the numbers were gained from internal
208 sources.

209

Publisher	Permalink to cost structure page
Frontiers	https://perma.cc/WKP4-R4D2
Open Library of the Humanities	https://perma.cc/9LEM-CDRL
Ubiquity	https://perma.cc/8U8K-AYZC
eLife	https://perma.cc/23GC-ARVB

210 **Table 2:** Published itemized cost structures from publishers/service providers.

211

212 For certain tasks, for example copyediting or
213 typesetting, there are hundreds of individual compa-
214 nies worldwide providing those services on a industry-
215 standard level. In our quote requests, we have consid-
216 ered only those with which we have collaborated in
217 real business life so far or from which we know the
218 performance and service level in detail from co-oper-
219 ations over two decades. Having compared the pricing
220 of those service providers with others, we found only
221 a very small variation of cost for such tasks, which jus-
222 tifies our practical approach. It was never our ambition
223 to perform an exhaustive but always incomplete mar-

224 ket study of service providers worldwide, but an at-
225 tempt to provide an authoritative documentation of
226 approximate current publishing costs as a valuable in-
227 formation tool for decision-makers and other stake-
228 holders in policy drafting, contract negotiations or
229 public discourse.

230 There are three main areas in which production
231 steps have to be considered: content acquisition, con-
232 tent preparation (production) and content dissemina-
233 tion/archiving. Importantly, 'content acquisition' does
234 not imply active acquisition of authors and/or manu-
235 scripts.

236

- 237 1. Content acquisition
- 238 a. Searching and assigning reviewers
- 239 b. Communication with reviewers
- 240 c. Communication with authors
- 241 d. Handling of re-submission process
- 242 e. Plagiarism check
- 243 f. Online submission system
- 244 g. CrossRef Similarity Check
- 245 h. CrossRef DOI for article
- 246 i. CrossRef DOI for 2 or more reviews
- 247 j. APC collection
- 248 2. Content preparation (production)
- 249 a. Manuscript tracking system
- 250 b. Production system check-in
- 251 c. Technical checking of manuscript
- 252 d. Copyediting
- 253 e. Language editing
- 254 f. Typesetting
- 255 g. Formatting figures/graphs/tables
- 256 h. Altmetric badge
- 257 i. XML and metadata preparation
- 258 j. Handling author corrections
- 259 3. Content dissemination/archiving
- 260 a. Web OA platform and hosting
- 261 b. CLOCKSS/Portico
- 262 c. OAPEN
- 263 d. Upload to Scopus, PMC, etc.
- 264

265 Pricing figures have been deducted by openly
266 available price lists of vendors, as for example for
267 Scholastica, Akron Aps, CrossRef, CLOCKSS (see Tables
268 1, 2). In all other cases where pricing list or fees were
269 not openly available on the web, prices were indicated

270 after a direct request for proposal or communicated
271 privately. For the latter we have checked with other
272 partners to validate that information. Some service
273 vendors have not split their services in a granular
274 manner but offer a full service for more steps of the
275 publishing workflow. In those cases we have tried to
276 split those costs or consider the full cost as part of one
277 of the scenarios (see below) which cover the complete
278 manuscript acquisition and article production pro-
279 cess.

280 Indirect or fixed costs

281 The calculation of per-article figures from costs
282 that do not accrue on a per-article basis (e.g., salaries,
283 annual fees, etc.) was based on the following assump-
284 tions: (i) The average STM article contains 12 printed
285 pages (Johnson et al. 2018). (ii) We estimated an aver-
286 age STM article to contain 10 non-text items such as
287 figures or tables. (iii) We also assumed an average re-
288 jection rate of 50% after conventional (pre-publica-
289 tion) peer-review with at least two reports and ten
290 contact requests to secure one reviewer. (iv) We as-
291 sume a desk-rejection rate of 10% after editorial re-
292 view. (v) We also base our staff costs on the granular
293 work load per article and not on full-time equivalents
294 (FTE). These assumptions entail that all editorial duties
295 (on average 7.5 person-hours per submitted manu-
296 script) are handled by in-house staff and none by aca-
297 demic editors, while peer-review is still performed by
298 volunteer academics. In this way, staff costs, including

299 overhead expenses, are calculated on a per-article ba-
300 sis. Salary costs are based on industry standards in
301 more economically developed countries for the differ-
302 ent editorial tasks. Overhead expenses can vary signif-
303 icantly depending on the profit and loss structure of
304 the publisher and include rent, repairs, depreciation,
305 interest, insurance, travel expenditures, labor burden,
306 telephone bills, supplies, taxes, accounting fees, etc.
307 We have estimated an average 33% overhead on top
308 of salary costs. The following publication tasks are
309 commonly covered by annual (membership) fees plus
310 an initial, one-time set-up or installment fee: Web OA
311 platform and hosting, CLOCKSS/Portico, OAPEN, Alt-
312 metric Badge and Crossref. Because these costs ac-
313 crue regardless of how many articles are published
314 (i.e., fixed costs), we have calculated per-article costs
315 for journals with different numbers of articles pub-
316 lished per year.

317 While some general fixed costs are covered by
318 salary overheads (see above), we deliberately chose to
319 not include certain fixed costs: Cost of sales have not
320 been considered because for open access journals no
321 longer sales representatives are required which have
322 to negotiate renewals of subscriptions with libraries
323 on an annual basis. We also excluded management
324 costs as these are highly variable and in large publish-
325 ers with many journals (and hence articles), per article
326 costs of management are often negligible. We realize
327 that this may be different for publishers which publish

328 low-volume journals but with nevertheless highly paid
329 executives (see Discussion). Because making an article
330 public (i.e., 'publishing') is distinct from locking it be-
331 hind a paywall, we have also not calculated the often
332 very significant paywall costs. While innovation (or ac-
333 quisition of innovative technologies) as well as brand-
334 ing and advertising/marketing are crucial for a com-
335 pany to succeed and thrive in a market in the long
336 term, we have also not included these costs as they
337 are not directly related to publishing scholarly articles.
338 Such costs would include conference attendance, ad-
339 vertisement in print, online, social media and search
340 platforms, as well as search engine optimization (SEO).
341 Similarly, government relations (lobbying) may be con-
342 sidered a necessary expense for any business, but as
343 it does not directly relate to the process of publishing
344 academic papers, we did not include these costs in our
345 calculations either. However, we do discuss the prob-
346 able extent to which these non-publication costs may
347 affect pricing.

348 Scenarios

349 The motivation for the above assumptions was
350 to combine a robust cost estimate (i.e., sourced from
351 measurable time efforts and industry salaries) with an
352 upper bound cost estimate which would come to lie
353 above most academic-run journals. We also calculated
354 a cost estimate for articles handled exclusively by vol-
355 unteer academics. Prices for journals where volunteer

356 and compensated editors cooperate, will hence fall
357 between these two extremes.

358 With a modern, decentralized/federated plat-
359 form providing publishing functionalities without jour-
360 nals, some of these steps become obsolete, while oth-
361 ers remain relevant. Steps that may become obsolete
362 include DOIs, long-term archiving such as CLOCKSS or
363 Portico, indices such as Scopus. Relevant steps re-
364 maining are typesetting/copyediting, XML prepara-
365 tion, format conversion, plagiarism checks.

366

Scenario A	Scholastica including ms submission, standard peer-review, track- ing system, OA webpage, hosting
Scenario A2	Scenario A, but PPPR
Scenario B	Generic service providers, ms submission, standard peer-review tracking system; OA webpage, hosting
Scenario B2	Scenario B, but PPPR
Scenario C	Generic service providers for content preparation with online plat- form; without external submission, reviewing, and tracking system; with DOI; no external hosting/archiving; volunteer editors
Scenario C2	Scenario C, but Scholastica

367 **Table 3:** Publishing scenarios for which detailed cost calculations have been performed.

368

369 We have grouped the various combinations of
370 tasks and publication options into six broad scenarios,
371 for which we have calculated all associated publication
372 costs (Table 3). These scenarios correspond either to
373 existing publishing options or to options that have
374 been discussed in the literature. For each of the six
375 scenarios, we have also calculated the same costs, but
376 assuming a 90% rejection rate (see raw data file).

377
378 All the data we have based our calculations on
379 are available at Figshare (DOI:
380 10.6084/m9.figshare.8118197).

381 Results

382 One of the first findings of our calculations is
383 that in order to employ at least one 50% FTE of an in-
384 house editor, a journal has to publish approx. 100 ar-
385 ticles per year or more. Hence, in the following, we will
386 base our estimates on journals publishing at least 100
387 articles per year (corresponding to 50% FTE) or 1,000
388 articles (corresponding to 5 FTEs), to show the spread
389 of fixed and indirect costs over the number of articles
390 published.

391 Our estimate of per-article publishing costs in a
392 conventional pre-publication peer-review (50% rejec-
393 tion rate) scenario where all editorial duties are per-
394 formed by in-house staff (Scenario B) ranges from
395 US\$643.61 for a journal that publishes 100 articles per

396 year down to US\$565.15 for such a journal that pub-
397 lishes 1,000 articles (or more, as the indirect costs be-
398 come increasingly negligible around this value). These
399 values consist of US\$266.53 direct publishing costs
400 (i.e., CrossRef Similarity Check, CrossRef DOI for an ar-
401 ticle, CrossRef DOI for two or more reviews, copyedit-
402 ing, typesetting, formatting figures/graphs/tables, alt-
403 metric badge, upload to Scopus and XML and
404 metadata preparation), US\$ 289.91 for editorial staff
405 and US\$8.72 to US\$87.18 for 1,000 to 100 articles, re-
406 spectively, in indirect costs (i.e., Web OA platform and
407 hosting, CLOCKSS, OAPEN, Altmetric Badge and Cross-
408 ref).

409 These numbers were calculated using generic,
410 full-service providers based in India, where applicable.
411 There are open access service providers that provide
412 packaged deals for the same services as these generic
413 service providers. We have calculated the same steps
414 using a well-known provider in this area, Scholastica
415 (Scenario A). Interestingly, these figures are slightly
416 higher: US\$ 374.08 for direct publishing costs and
417 US\$5.92 to US\$59.18 for 1,000 to 100 articles, respec-
418 tively, for indirect costs (editorial staff costs remain the
419 same).

420 While these costs have been calculated for a ge-
421 neric journal with 50% rejection rate, per-article costs
422 will increase with increased rejection rates and de-

423 crease with less rejections as in, e.g., a post-publica-
424 tion peer-review (PPPR) model. In a journal that uses
425 generic service providers and publishes all submitted
426 manuscripts as PDF preprints with a DOI before per-
427 forming otherwise identical peer-review as described
428 above (i.e., PPPR with in-house editors and volunteer
429 reviewers), per article editorial services drop from
430 US\$289.91 to US\$140.69 (Scenario A2/B2), with all
431 other costs remaining nearly identical. Conversely,
432 prestigious journals with rejection rates of around
433 90% see their costs rise to US\$1053.87 for 100 articles
434 per year or US\$770.53 for the larger journals with
435 about 1,000 articles per year (generic service provid-
436 ers).

437 These numbers also show that for a conven-
438 tional journal today, where academics perform their
439 editorial duties on a volunteer basis (i.e., Scenario B,
440 but no editorial costs as editor salaries are paid for by
441 their academic institutions), direct publication costs
442 come to lie at US\$266.53 with generic service provid-
443 ers and total costs depend on the scale at which the
444 journal operates. Small journals with 100 articles
445 would face average per article total publication costs
446 of US\$353.71, while journals with 1,000 or more arti-
447 cles would only face costs of US\$275.25 or less per
448 published article. Even at the highest convenience for
449 a small, volunteer-run journal, costs come to lie at
450 US\$454.63 where a full-service provider (Scholastica)

451 handles all of the technical aspects of the work (Sce-
452 nario C2).

453 The above calculations (summarized in Table 4)
454 demonstrate economies of scale. The more articles
455 are being published, the lower the costs for each arti-
456 cle, approaching the fixed costs for each article.

457

scenario	total	direct	indirect	in-house staff
Conventional peer review, Scholastica, 100 articles (A)	723.16	374.08	59.18	289.91
Conventional peer review, Scholastica, 1,000 articles (A)	669.90	374.08	5.92	289.91
Conventional peer review, generic providers, 100 articles (B)	643.61	266.53	87.18	289.91
PPPR, Scholastica, 100 articles (A2)	597.74	369.88	87.18	140.69
Conventional peer review, generic providers, 1,000 articles (B)	565.15	266.53	8.72	289.91
PPPR, Scholastica, 1,000 articles (A2)	519.28	389.88	8.72	140.63
PPPR, generic providers, 100 articles (B2)	469.32	241.45	87.18	140.69
Volunteer editors, Scholastica, 100 articles (C2)	454.63	358.33	47.18	49.12
Volunteer editors, Scholastica, 1,000 articles (C2)	412.16	358.33	4.72	49.12
PPPR, generic providers, 1,000 articles (B2)	390.86	241.45	8.72	140.63
Volunteer editors, generic providers, 100 articles (C)	237.35	141.05	47.18	49.12
Volunteer editors, generic providers, 1,000 articles (C)	194.89	141.05	4.72	49.12

458 **Table 4:** Different scenarios of journal organization, ordered by total per article costs (in
 459 US\$). The scenarios are labeled with A, A2, B, B2, C, C2 (see table 3).

460

461

462

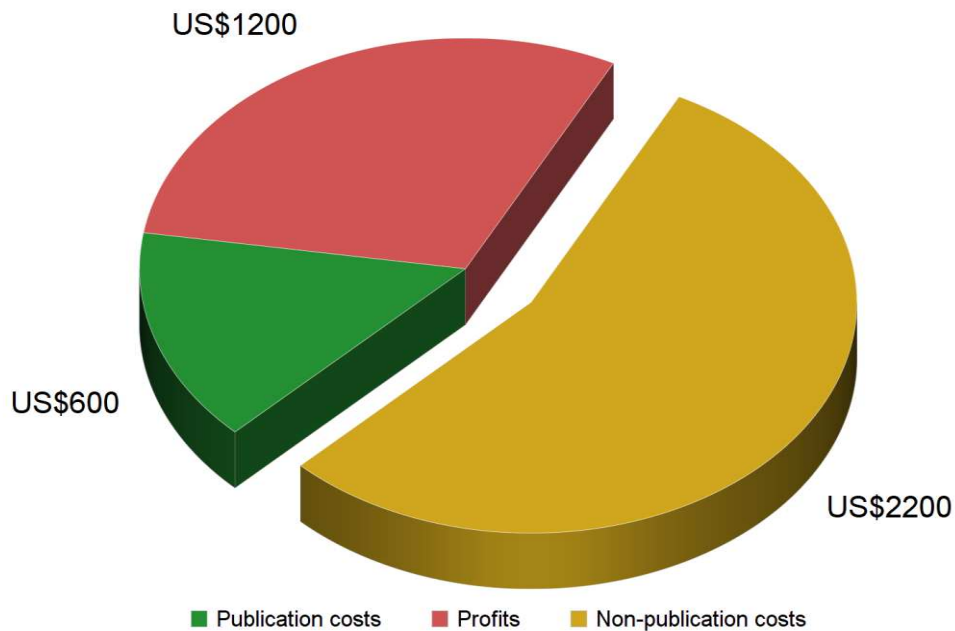
463

Because of the economies of scale and recent calls for the replacement of journals with a modern publishing platform (Brembs 2019; Stern & O'Shea

464 2019; Grossmann 2015; Nosek & Bar-Anan 2012; Hart-
465 gerink 2019), we have also calculated the cost of pub-
466 lishing the annual output of the STM community, ap-
467 prox. 3 million articles, on such a platform that facili-
468 tates PPPR organized by academic editors on a single,
469 decentralized, federated platform running modern
470 software solutions. Such a platform would dispose of
471 several production steps which are necessitated by
472 the current balkanization of the literature in different
473 journals published by different publishers, but keep
474 others (see Methodology). In this scenario, the indirect
475 and fixed costs per article approach zero due to the
476 high number of published articles (but see Discus-
477 sion), such that the only remaining costs would be the
478 direct publishing costs of US\$190.17 per published ar-
479 ticle.

480 Finally, taking a ballpark cost figure of US\$600
481 for a scholarly article with full editorial services (i.e.,
482 scenario A/B) and comparing it to the low end of the
483 average price estimate for a subscription article of
484 about US\$4,000, it becomes clear that publication
485 costs only cover 15% of the subscription price (Fig. 1).
486 Assuming a conservative profit margin of 30% (i.e.,
487 US\$1,200 per article) for one of the large publishers
488 (McGuigan & Russel 2008; Larivière et al. 2015;
489 Beverungen et al. 2012; Harvie et al. 2012), there re-
490 mains a sizeable gap of about US\$2,200 in non-publi-
491 cation costs, or 55% of the price of a scholarly sub-
492 scription article (Fig. 1).

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494

495 **Fig. 1:** *Subscription price and cost items.* Assuming the commonly accepted US\$4,000 price
496 tag for a subscription article, published profit margins of 30% and our calculation of
497 US\$600 in publication costs for a full-service subscription article (scenario A/B, see Table
498 4), there remain US\$2,200 in non-publication costs per article.

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Discussion

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Since the 1990s, it has been recognized that the prices of scholarly journals were escalating at unsustainable rates (Douglas 1990). In the last 30 years, this “serials crisis” has never been coherently addressed, let alone solved. With this work, we aim to provide more financial evidence for future evidence-based policies addressing the affordability problem of scholarly communication (Chan 2004; Harnad et al. 2004).

509 Subscription prices and publication costs

510 Not only current discussions are addressing the
511 affordability problem in the unit of cost per article (Van
512 Noorden 2013; Schimmer et al. 2015; Odlyzko 2013;
513 Johnson et al. 2018; Odlyzko 1995; Jahn & Tullney
514 2016; Solomon & Björk 2016; Morrison 2018a) and we
515 follow this precedent. Drawing from publicly available
516 price lists and industry-standard service costs, we find
517 that publishing costs per article vary from US\$194.89
518 to US\$723.16, depending on the level of service and
519 publishing volume (Table 4). It is important to note
520 that these are conservative estimates, likely to consti-
521 tute upper bounds, where innovation and changes in
522 practice can be expected to decrease costs.

523 Perhaps not surprisingly, the convenience of
524 outsourcing the main publishing services to a special-
525 ized full-service provider comes with a small increase
526 in cost (scenario A vs. scenario B), when compared to
527 an itemized sourcing of publishing services. In our cost
528 estimate, we have not factored in the management
529 cost of sourcing the itemized services, as we have not
530 included company management in our calculations.
531 Any decision between these two options will thus have
532 to be made after factoring in such costs as well.

533 Even in the rare, most expensive case, these
534 costs compare very favorably to the current subscrip-
535 tion pricing of around US\$4,000-5,000. Our highest
536 value encompasses conventional, journal-based pre-

537 publication peer-review with a generic 50% rejection
538 rate at a small journal (~100 articles per year) where
539 all management of peer-review is performed by in-
540 house editorial staff with no volunteer academic edi-
541 tors. Our data suggest that increasing only the rejec-
542 tion rate, for example from 50% to 90%, leads to an
543 increase in publication costs of around 30-40% (e.g., in
544 scenario B from US\$565.15 to US\$770.53 for 1,000 ar-
545 ticle journals or from US\$643.61 to US\$1,053.87 for
546 100 article journals). Apparently, this is a consequence
547 of the respective increase of direct personnel ex-
548 penses for managing the peer review process and
549 communicating with both reviewers and authors for
550 classical pre-publication peer review. As currently
551 most highly selective journals publish on the order of
552 800-900 research articles per year about US\$1,000 per
553 article can be seen as an upper bound of total publica-
554 tion costs at such journals.

555 Article processing charges and publication costs

556 The reported average APCs charged by the mi-
557 nority of journals with such fees vary between
558 US\$1,400-2,200 depending on the sample (see above
559 and, e.g., Table 2). The large difference between these
560 values and even our most expensive cost estimate is
561 at least partly consistent with our hypothesis that the
562 quasi-monopolistic situation of the publishers, due to
563 the non-substitutability of their goods and services, al-
564 lows them to adopt a value-based pricing strategy also
565 in the APC-OA case, similar to subscription pricing. It is

566 therefore straightforward to hypothesize that any pol-
567 icy that fails to address the non-substitutability prob-
568 lem in scholarly communication will also fail to solve
569 the affordability problem and lead to a similar market-
570 failure as in the subscription model. An analogous ar-
571 gument has previously also been endorsed by the Eu-
572 ropean Commission Directorate-General for competi-
573 tion (Tennant & Brembs 2018), even before our calcu-
574 lations were available. Further reducing the odds of
575 APC-OA solving the affordability problem is the fact
576 that authors are not only price-insensitive (Khoo
577 2019), but seem to prefer publishing in journals that
578 charge APCs as opposed to those that do not, as
579 evinced by the fact that most OA articles are published
580 in the minority of journals that charge APCs (Crawford
581 2019). Above and beyond authors' preference for jour-
582 nals with APCs over those without, among those APC
583 journals, authors are incentivized to publish in high-
584 APC, rather than low-APC journals, because APCs in-
585 crease with the prestige of the journal (Tennant & Lo-
586 max 2019; Andrew 2012). Consequently, a recent
587 study observed APC increases of 2.5-6 times inflation
588 over six years in their sample (Khoo 2019). This con-
589 verging evidence all points towards both APC-OA and
590 subscriptions to suffer from analogous flaws which
591 lead to hyperinflation and market-failure in both
592 cases. Our data now add further evidence in support
593 of this hypothesis.

594 Aiming for a cost-plus market

595 Starting from current subscription pricing of
596 around US\$4,000-5,000 per article (Van Noorden
597 2013; Schimmer et al. 2015; Odlyzko 2013; Johnson et
598 al. 2018; Odlyzko 1995), we confirm previous esti-
599 mates that current subscription moneys are sufficient
600 to pay for a complete transition to OA, even at current
601 inflated APCs on the order of about US\$2,000 per arti-
602 cle (Schimmer et al. 2015; Odlyzko 2013; Johnson et al.
603 2018; Jahn & Tullney 2016; Solomon & Björk 2016;
604 Morrison 2018a). Calculated globally, this hypothetical
605 transition to APC-OA would cut the US\$10 billion
606 world-wide annual subscription budget roughly in
607 half, at least in the short term. At the same time, if
608 there were a way to enforce cost-plus pricing strate-
609 gies in publishers, even the current prices would at
610 least be 100% above actual publishing costs at the
611 highest level of service and even more for a lower level
612 of service and higher article volume, which is the norm
613 at many journals. Thus, the mere transition to a mar-
614 ket where the current value-based pricing strategies
615 are not deployed any more, all else being equal,
616 stands to save the global taxpayer at least 75% of the
617 current subscription budget, or the equivalent of
618 about US\$7.5 billion annually. However, the current
619 journal system does not provide for such a solution as
620 journals are non-substitutable (see above).

621 Replacing journals with a modern, server-
622 based, decentralized solution (Brembs 2019; Stern &

623 O'Shea 2019; Grossmann 2015; Hartgerink 2019) im-
624 plements substitutability of services and, hence, com-
625 petition, providing for the largest savings: even when
626 the volume of articles amounts to 3 million per year
627 (Johnson et al. 2018), the global taxpayer stands to
628 save about 95% of the current subscription budget, or
629 the equivalent of approx. US\$9.5 billion annually, on
630 publishing prices.

631 Cost-plus pricing technically feasible today

632 There are more conclusions to be drawn from
633 the evidence we provide here. For one, while the cur-
634 rent APC-OA prices would, if applied universally, ad-
635 dress the affordability problem and substantially
636 lower the cost to the taxpayer in the short term, the
637 available evidence suggests that the current value-
638 based pricing strategy of publishers (together with the
639 price-insensitivity of authors (Khoo 2019)) is likely to
640 quickly eat into these gains and again lead to unsus-
641 tainable inflation, as in the subscription case.

642 Second, because the workflow we model con-
643 sists of verifiable, modular components, we demon-
644 strate that a cost-plus pricing scheme is possible to-
645 day. Phrased differently, customers of commercial
646 publishers can use these numbers as tools in contract
647 negotiations to demand more cost-oriented contracts.
648 However, at the same time, as long as the ultimate lev-
649 erage in such negotiations, namely to walk away and

650 opt for the goods and services of a competitor, re-
651 mains inaccessible due to the non-substitutability
652 problem, the effectiveness of this tool will remain
653 comparatively limited.

654 Third, our calculations show that with publish-
655 ing volumes exceeding 1,000 articles per year, fixed
656 costs shrink below 1% of the direct article costs and
657 become negligible. This was expected and already
658 concluded in a previous analysis (Bogich & Ballesteros
659 2016). These insights are important for designing a
660 transition towards a scholarly publishing platform in-
661 stead of journals.

662 Fourth, due to the limited possibility in dividing
663 labor contracts into arbitrarily small portions, we find
664 that journals with volumes below approx. 100 articles
665 per year would be best served financially if they oper-
666 ated on the concept of volunteer academic editors
667 handling the peer-review, instead of in-house staff.

668 Targeting the non-substitutability problem

669 Synthesizing all of these conclusions, it be-
670 comes clear that any solution to the affordability prob-
671 lem must aim at eliminating non-substitutability and
672 strive towards large volume strategies. Historically,
673 non-substitutability has been solved with, e.g., indus-
674 try standards that allow substitution of products and
675 services. For instance, multimedia standards allow for
676 media from any producer to be played on any player.

677 In the case of scholarly communication, the non-sub-
678 stitutability is granted via prevention of duplicate pub-
679 lications of discoveries in different journals together
680 with prestige stratification of the journals. Both of
681 these factors are conveyed by the journals where the
682 individual articles are published. Consequently, one
683 straightforward approach to mitigate this non-substi-
684 tutability is to eliminate journals as venues and imple-
685 ment technical standards to allow publication services
686 to become substitutable.

687 One technical implementation of this principle
688 is to collect all articles in a single, decentralized, feder-
689 ated venue that is governed by the scholarly commu-
690 nity and designed using common, evolvable standards
691 to allow for the substitution (and, consequently, com-
692 petition) of service providers (Brembs 2019; Stern &
693 O'Shea 2019; Grossmann 2015; Hartgerink 2019). This
694 concept mimics other infrastructure arrangements
695 such as water, electricity, HVAC, email, etc. This ap-
696 proach would, at the same time, solve the problem of
697 large publication volume: the STM field is on course to
698 publish about 3 million articles every year (Johnson et
699 al. 2018), allowing fixed costs to effectively converging
700 towards zero in the per-article currency (Bogich & Bal-
701 lesteros 2016). However, even if the per-article costs
702 of such infrastructure are negligible, they remain a
703 substantial item in absolute terms that scholarly insti-
704 tutions need to pay. In a recent tender, the European
705 Commission provided an indicative estimate for the

706 cost of “development of the platform, its services and
707 business processes, communication and sustainabil-
708 ity” (European Commission 2017), of around 250,000€
709 per year. Perhaps an order of magnitude higher costs
710 may be estimated to implement and run a system that
711 is scaled for the world-wide scholarly output, arriving
712 at approx. US\$3 million per year. Given that there are
713 about 10,000 universities world-wide (Förster 2019)
714 (plus a large number of non-university research insti-
715 tutions) which would stand to participate, these costs
716 to establish and maintain such an infrastructure
717 would likely amount to approx. US\$300 per institution
718 per year. Even if only the 3,300 European Union uni-
719 versities (European Commission 2003) were to imple-
720 ment and run the platform by themselves with other
721 institutions only contributing article costs, these indi-
722 rect costs would amount to less than US\$1,000 per
723 year and institution. These numbers demonstrate that
724 even under conservative estimates, the fixed costs of
725 a publishing platform remain within feasible bounds.
726 While these numbers demonstrate not only the imme-
727 diate feasibility of the transition towards such a plat-
728 form, but, indeed, the fiscal imperative for it, it is far
729 from clear how the transition should be accomplished
730 practically. Because it is beyond the scope of this arti-
731 cle to provide such policy recommendations, we refer
732 to those already provided elsewhere (see, e.g.,
733 Brembs 2019; Stern & O’Shea 2019).

734 Such a solution would preserve the rules aimed
735 at preventing duplicate publication, but eliminate jour-
736 nal hierarchy as a signal for prestige. Given that, at
737 least in the experimental sciences, journal prestige is
738 associated with lower reliability (Brembs et al. 2013;
739 Brembs 2018), it may be argued that eliminating jour-
740 nal prestige ought to be a goal in and of itself, in order
741 to tackle any decline in reproducibility (e.g., Karp 2018;
742 Baker 2016; Schooler 2014; Berg 2018; Sayre & Riegel-
743 man 2018; Saltelli & Funtowicz 2017; Lilienfeld 2017;
744 Everett & Earp 2015; Brembs 2019).

745 **Non-publication costs**

746 If the lowest publication costs for journals with
747 volunteer editors constituted merely 5-10% of current
748 subscription prices and publicly reported publisher
749 profits only amount to an additional 30-40%, which
750 non-publication costs are publishers currently facing
751 and taxpayers paying for? While these costs are
752 opaque and variable between publishers and, indeed,
753 between journals, some estimates can be made from
754 publicly available data. If one assumes revenue of
755 about US\$4,000 per subscription article (i.e., on the
756 low end of the converging estimates), a conservative
757 30% profit margin (i.e., US\$1,200 per article) for one of
758 the large publishers (McGuigan & Russel 2008; Lari-
759 vière et al. 2015; Beverungen et al. 2012; Harvie et al.
760 2012) and generous publication costs of US\$600 per
761 article (scenario A/B; table 4), then there remains a
762 sizeable gap of about US\$2,200 in non-publication

763 costs per article - more than the sum of publication
764 costs and profits combined, or 55% of the subscription
765 cost of a scholarly article (Fig. 1). While some of these
766 costs may be considered necessary for any business,
767 none of them are associated with publishing primary
768 research articles (see Methods).

769 Running a business: Management

770 While our cost calculations include generic run-
771 ning costs such as rent, repairs, depreciation, interest,
772 insurance, travel expenditures, labor burden, tele-
773 phone bills, supplies, taxes, accounting fees, etc., we
774 have explicitly omitted some indirect costs such as
775 management cost and paywalls. For instance, accord-
776 ing to their 2016 tax statement, the New England Jour-
777 nal of Medicine spends 4% of its publication revenue
778 on their top ten management staff alone (which would
779 translate to about US\$160 per article if applied to our
780 example above; Fig. 1).

781 Preventing access: Paywalls

782 Subscription journals also face costs associated
783 with paywalls. It's difficult to estimate the cost of such
784 technology for publishers, but the cost of a new pay-
785 wall for the New York Times was reported to lie be-
786 tween US\$25-50 million (Pulley 2011; Kramer 2011).
787 Alternatively, as the functional distinction between
788 subscription articles and OA articles is precisely the
789 missing paywall in OA articles, one could also assume
790 that publishers arrive at their current APC pricing of

791 around US\$2,000 by subtracting paywall costs from
792 their subscription price. This assumption would entail
793 paywall costs of approx. US\$2,000 per article (i.e., the
794 difference between APC and subscription pricing).

795 On top of the technical cost of a paywall, one
796 may also consider the legal fees for defending pay-
797 walls for this cost item. Publishers have a track record
798 of litigation with regard to articles outside of their pay-
799 walls and regularly seek damages in court for actual or
800 perceived threats to their subscription business
801 model (Hansen 2019; Chawla 2017; Van Noorden
802 2017; Association Of American Publishers 2015; Cox
803 2018; Flaherty 2013; Schiermeier 2017). These costs
804 accrue by seeking to enclose the scholarly literature
805 within the paywalls of publisher via alternative routes
806 in addition to the digital paywalls.

807 News, advertising, sales, marketing, public relations: branding

808 Another cost item is publishing non-research
809 content. For instance, for 2016, PubMed lists a total of
810 1,632 articles published by the New England Journal of
811 Medicine, while Clarivate Analytics only counts 328 ar-
812 ticles for their Impact Factor. Assuming that only the
813 latter articles amount to primary research publica-
814 tions, this journal's revenue also pays for 1,304 non-
815 research articles. Similar numbers also hold for other
816 prestigious journals (e.g.: Nature: 880/2765, Science:
817 805/1938; research/total), often with their own jour-
818 nalist and editorial staff commissioning articles and/or

819 reporting themselves on research and policy news.
820 However, the number of journals where this can con-
821 stitute a significant fraction of their total costs is pre-
822 sumably small, likely restricted to the most prestigious
823 journals.

824 Prestigious journals also often practice active
825 author or materials acquisition, by traveling to confer-
826 ences and laboratories, building networks in a strat-
827 egy to entice the next exciting research finding to be
828 published in their journals. Active author acquisition
829 accrues costs both in terms of travel and time spent
830 networking and communicating with authors that is
831 not covered in our cost estimates (see Methods).

832 Sometimes, new journals also need to engage
833 in such author acquisition practices, which, perhaps,
834 can be best subsumed under general marketing or
835 public relations costs required for building and main-
836 taining a brand. These marketing costs also include,
837 e.g., advertising in various venues targeting both au-
838 thors and subscribers. For many publishers it is also
839 common to promote their brand at conferences and
840 institutions with, e.g., hosted speakers, travel grants or
841 sponsored awards.

842 Because of the complex, time-consuming nego-
843 tiations with libraries on ever tighter budgets due to
844 the hyperinflationary subscription price increases,
845 publishers also need to employ expert sales teams.
846 The task of these sales teams is not only to find the

847 most irresistible way to package and bundle subscrip-
848 tion journals and/or databases, but also to devise the
849 most inexorable psychological strategy for their nego-
850 tiations with librarians. These sales teams need to op-
851 erate in close connections with the various advertis-
852 ing, marketing and public relations teams of the pub-
853 lisher to accomplish a coherent brand image. One may
854 argue that in times of OA, these sales costs are not
855 necessary expenses any more and more associated
856 with paywall costs than with publication costs. On the
857 other hand, in an OA world, one may argue that brand-
858 ing was never more important for author acquisition.

859 New technologies: innovation and acquisitions

860 Publishers also need to invest in innovation, in
861 order to stay current with their technologies and func-
862 tionalities. While scholarly publishers have been quick
863 to transition from print to web-based technologies in
864 the past, the digital functionalities of most of the schol-
865 arly literature today lag at least a decade behind cur-
866 rent functionalities of other digital objects outside of
867 the scholarly literature. The level of investment in in-
868 novation thus remains unclear and its effects ques-
869 tionable. Instead of investments into their own tech-
870 nological innovation, publishers today appear to ac-
871 quire companies that have invented desired function-
872 alities around the scholarly workflow, with the goal to
873 provide services beyond publications (Bosman & Kra-
874 mer 2018; Crunchbase 2019; Posada & Chen 2018;
875 Campfens 2019).

876 Government relations: Lobbying

877 Most international publishers, as any other corporation,
878 also spend significant amounts of money on government relations (i.e., lobbying). Some of these
879 corporations employ staff at the vice president level not only in the most important research nations, but
880 also at the level of supra-national bodies such as the European Commission (Jonathan Tennant 2018).
881 These staff, in turn, employ assistants and other members of their teams. Obviously, the task of these employees
882 is to protect current revenue streams, e.g., subscription or APC income. For instance, one publisher,
883 Elsevier, spends more than 400,000€ per year on lobbying at the level of the European Commission
884 alone (Anon 2018). The consequences of such efforts have been observable, e.g., in the so-called “Finch Report”
885 in the UK (Finch 2012), which surprised many commentators with its publisher-friendly recommendations
886 (see, e.g., Prior 2013; Jonathan Tennant 2018).
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895 Lack of competition: Inefficiencies

896 Finally, with profit margins exceeding 30% in many cases, there may be less pressure to optimize
897 the workflow to cut down further on already marginal publication costs (on the order of 15% of total costs in
898 the example above, Fig. 1). It is thus conceivable that large publishers, where the economies of scale already
899 have decreased costs, are operating at such low efficiencies that their publication costs may come to
900 lie higher than we calculated.
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905 Which non-publication costs should remain bundled up with pub-
906 lishing?

907 Regardless of all of these estimates necessarily
908 remaining vague and imprecise, the fact remains that
909 the scholarly community must eventually make a
910 number of decisions, if it is to tackle the affordability
911 problem. Which of the above non-publication costs
912 such as lobbying, start-up acquisition, executive sala-
913 ries in the millions of US\$, non-research article pub-
914 lishing, marketing/advertising, sales/negotiations, in-
915 efficiencies etc., should remain bundled up with the
916 process of publishing scholarly research articles?
917 Which of these costs are avoidable, which necessary
918 and which even desirable? Are profit margins of 30-
919 40% on taxpayer funds tolerable?

920 In fact, one may even ask whether many of the
921 services we list as part of the scholarly publishing
922 standard are actually necessary for scholarly publish-
923 ing. After all, journals such as the Journal of Machine
924 Learning Research, Discrete Analysis or the Journal of
925 Open Source Software publish their articles with inter-
926 nal costs below US\$10 (Jon Tennant 2018). Likewise,
927 the preprint archive arXiv publishes their articles at
928 similar costs (Cornell University Library 2010).

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