

# OPEN ACCESS AS A CRUDE SOLUTION TO A HOLD-UP PROBLEM IN THE TWO-SIDED MARKET FOR ACADEMIC JOURNALS\*

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We analyze a model in which journals cannot commit to subscription fees when authors (who prefer low subscription fees because this boosts readership) make submission decisions. A hold-up problem arises, manifested as excessive subscription fees. Open access is a crude attempt to avoid hold up by eliminating subscription fees. We assess the profitability and efficiency of traditional relative to open-access journals in a monopoly model (with extensions to nonprofit, bundled, hybrid, and competing journals). We apply the theory to understand the evolving market for academic journals in the Internet age and policies currently being debated such as an open-access mandate.

\*We are indebted to the editor, Justin Johnson, and two anonymous referees for insightful suggestions, which substantially improved the quality of the paper. We are also grateful to Mark Armstrong, Laurens Debo, Sumit Joshi, Simon Loertscher, Jeff Mackie-Mason, David Malueg, Seema Nanda, Tim Simcoe, Lars Stole, and seminar participants at American University, Boston University, Dartmouth College, George Washington University, MIT, New York University, Ruhr-Universität Bochum, Santa Clara University, Tulane University, the University of Chicago, the University of Göttingen, Yale University, the Cologne Summit on Open Access Publishing, the Emory University Symposium on Open Access and Digital Preservation, the International Industrial Organization Conference (Chicago), and the NBER Workshop on Scholarly Communication, Open Science, and Its Impact (Cambridge, MA) for helpful comments. This paper grew out of an earlier project, “The Economics of Open-Access Journals,” conducted under grants from the Open Society Institute, NET Institute, and Stigler Center for Study of Economy and State at the University of Chicago Graduate School of Business. Funding for work on this paper was provided by the Sloan Foundation, grant #G-2012-10-20, which the authors gratefully acknowledge.

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## I. INTRODUCTION

The high and growing subscription fees for scholarly journals, dubbed the “serials crisis,” claimed to drain library budgets and restrict readership, has been a source of outrage in the academic community. Evidence of these pricing trends in our own field, economics, can be seen in Table I in the data appendix (Appendix A). Following Bergstrom [2001], this table compares subscription fees charged by for-profit journals to those charged by non-profits (a proxy for journal costs), focusing on the best-known economics journals.<sup>1</sup> The gap between the mean subscription fees, already noticeable in 1985 (\$199 for for-profits compared to \$52 for non-profits) exploded. By 2016, while the mean non-profit fee grew only eight fold to \$479, the mean for-profit fee grew 20 fold to \$4,134.<sup>2</sup>

The “serials crisis” has prompted calls that an alternative business model be used for journals: open access.<sup>3</sup> An open-access journal allows all readers to freely access its articles online, leveraging the Internet’s ability to distribute electronic media at near zero marginal cost. Revenue to cover publication costs (and generate profits for commercial publishers) comes from author fees.<sup>4</sup> Based on data from the leading registry, the Directory of Open Access Journals (DOAJ), Figure 4 (also provided in the data appendix) documents the rapid growth in the number of open-access journals, around 33% annually, reaching over 10,000 by the end of 2015.<sup>5</sup> While some open-access journals are of dubious quality (Bohannon 2013), the quality of others is indisputably high: for example, *PLOS Biology*, was ranked second among all biology journals according to 2015 Journal Citation Reports (JCR) impact factor. Free to readers, open-access journals may charge substantial author fees: for example *PLOS Biology* charges \$2,900 to authors of accepted papers.

Open access made headlines when the largest journal publisher, Elsevier, filed a lawsuit in June 2015 against Alexandra Elbakyan, seeking an injunction against the operation of the Sci-Hub website she created (Murphy 2016). Sci-Hub provides free access to pirated copies of a vast corpus of over 58 million academic articles, including Elsevier’s and JSTOR’s entire archives. The injunction granted by a U.S. federal judge failed to shut down Sci-Hub’s operations because the injunction is not enforceable in Russia, where Elbakyan remains in hiding. Turning from piracy, more formal policies such as open-access mandates are the continued subject of debate among officials. The U.S. Senate is considering legislation (the Fair Access to Science and Technology Research or FASTR Act) requiring that any federally funded research must be openly accessible no more than six months after publication. A number of foundations including Wellcome Trust and the Gates Foundation also mandate open access for research they fund.

The fee structure of journals has potentially important consequences for social welfare. Subscription prices rose to the point where libraries began to cancel significant titles (Weiss 2003, Howard 2010). Such cancellations can harm both readers and authors—readers because their access to past research is limited, and authors because fewer readers will reduce their impact and citations

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<sup>1</sup>See Bergstrom and Bergstrom [2004] and Dewatripont *et al.* [2006] for related, comprehensive studies of journal prices as a function of profit status.

<sup>2</sup>McCabe [2002] documents similar trends for biomedical journals, showing that average library subscription fees more than doubled from the 1988–1994 period to the 1995–2001 period.

<sup>3</sup>See Murphy [2016] for a journalistic account of the open-access movement and Willinsky [2006] for policy analysis.

<sup>4</sup>We generally use “open access” to mean what librarians refer to as “gold” open access, i.e., free immediate access through the journal’s website to all of its content. This is distinct from “green” open access, covering the case in which free access may be to a pre-print version of the article on the author’s website or in which the free access on the journal’s website comes after an embargo period. Armstrong [2015] discusses the varieties of open access and analyzes the efficiency of mandating certain forms.

<sup>5</sup>The number of open-access journals in economics has been growing at about the same 33% pace as the general rate, totaling more than 500 journals by the end of 2016 (see Panel B of Figure 4). Most of these are relatively low-impact. Only the two published by the Econometric Society rank among the top 200 economics journals according to the JCR’s 2015 impact factor: *Theoretical Economics*, ranked 66, and *Quantitative Economics*, ranked 116.

at the margin.<sup>6</sup> Open access may not be the panacea commentators suggest. It is not obvious that commercial publishers will readily adopt the model. Moreover, the higher author fees associated with open access may lead to different set of distortions, offsetting purported benefits of open access. Since journals are a channel for dissemination of knowledge in the economy, understanding the frictions in this channel may have much broader implications for the economy as a whole. Another reason for analyzing the journals market for an academic audience is that it is one of the few markets that academics participate in as producers and consumers and exercise some control over as journal founders and editors.

In this paper we construct a model of journals as intermediaries between authors and readers in a two-sided market. Each side of the market benefits from externalities provided by the other: an author benefits from the citations and prestige obtained from additional readers, a reader from the information contained in additional articles. The key feature we add to a standard two-sided-market model, which we argue captures the crucial difference between traditional and open-access journals in practice, is a commitment assumption. We assume that a traditional journal cannot commit to subscription fees when soliciting submissions from authors; it can only commit to the submission fee. This assumption captures the empirical fact we will document that articles receives the bulk of their citations well after the the year of publication, whereas no traditional journal quotes subscription fees beyond the current year. Although these circumstances may not have posed a commitment problem in the print era—anyone subscribing when the article was published possessed the print copy, affording permanent future access—they do in the present digital era in which access is effectively rented each year. Under present circumstances, authors would prefer the journal to maintain low subscription fees, attracting a wide readership for their articles. However, everyone correctly foresees that the journal will extract the monopoly rent for access to the articles from subscribers in the future. One crude commitment mechanism is available to a journal. While it cannot commit to a specific positive subscription fee, it can commit not to charge readers at all, thus becoming an open-access journal.

Our baseline analysis is for the simple case of a monopoly, for-profit journal. If it operates as a traditional journal in equilibrium, it ends up setting a subscription fee that is too high, not just the usual sense of being higher than a social planner would choose, but higher even than the journal itself would choose if it could commit *ex ante*. The journal-author transaction suffers from a classic hold-up problem à la Williamson [1975]. For some parameters, the hold-up problem is so severe that the journal resorts to open access to solve it, even though open access forces the journal to give up all the profit from the reader side. In particular, open access is more profitable than traditional in the limit as the values that authors obtain from being read grow large relative to the values that readers obtain from the articles, as we prove for arbitrary logconcave distributions of values. The opposite is true—traditional is more profitable than open access—in the opposite limit of high reader relative to author values.

In these two limiting extremes, the more profitable mode of operation is also the socially efficient one. In intermediate cases, however, there can be distortions in the journal's choice of business model. These distortions have a certain asymmetry. We show that for arbitrary distributions there are always cases with excess traditional access (i.e., the journal chooses traditional access when open access would have been more efficient) but for a class of distributions at least (nonincreasing, logconcave), there is never excess open access. To understand why, it is helpful to think of the access mode as determining the quality of the product purchased by authors, with open access being the high-quality product. It is well-known since Spence [1975] that the ranking between the monopoly and socially efficient level of quality is ambiguous in general, depending on whether the marginal

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<sup>6</sup>Using panel-data methods to identify causality, McCabe and Snyder [2014] estimate an 8% effect of open access on citations.

or the average consumer values quality more. An additional factor leading the ranking to be less ambiguous for the two-sided market under consideration here is that high quality on the author side of the market is generated by giving away subscriptions on the reader side. This giveaway is costly for the monopolist (losing all the revenue on the reader side) but may benefit the social planner (possibly gaining social welfare on the reader side, in any event not counting lost revenue as an opportunity cost but just a transfer from producers to consumers). For a class of distributions, this additional factor ensures the social planner favors high quality more than a monopolist.

In Section V, we consider a number of extensions of practical relevance including nonprofit, bundled, and hybrid journals (offering open access to authors for a premium). We apply our model to understand consequences of important trends in the journals market including the move from print to digital journals and the rise of “megajournals” such as *PLOS One*, publishing tens of thousands of articles per year. A featured extension returns to the policy with which we opened the introduction, an open-access mandate, using the model to analyze its welfare effects. While the mandate can generate welfare gains in those cases in which the equilibrium otherwise involves inefficient traditional access, it can generate large losses by preventing traditional access when it would have been efficient. In particular, this happens when author benefits are small relative to reader benefits because the high submission fee associated with open access reduces submissions, depriving high-value readers of articles. For the range of parameters examined in our numerical example, the maximum welfare loss turns out to be almost twice the maximum welfare gain. Blanket approval of a mandate can be socially quite harmful.

Another featured extension moves from a monopoly to competing journals. Because authors cannot submit to multiple journals simultaneously (singlehoming in two-sided-markets parlance), a journal that has assembled a volume of articles has monopoly power vis-à-vis this volume’s readers. A traditional journal will fully exercise this monopoly power because it cannot commit to do otherwise. Monopoly rents are not necessarily dissipated in the competition among traditional journals for authors ex ante because submission fees cannot go negative. These three frictions—singlehoming authors, lack of commitment to subscription fees, and a nonnegativity constraint on submission fees—together create a “competitive bottleneck” among traditional journals, leading to imperfect competition among them even though they are perfect substitutes.<sup>7</sup> Competition among open-access journals is in effect more intense. Their commitment to zero subscription fees prevents them from earning rents on the reader side. Competition for authors squeezes all the rents from that side as well (the non-negativity constraint on submission fees does not bind for open-access journals because they hit the non-negativity constraint on profits first). The drawback of intense competition is that it may deter entry by more than one open-access journal. An open-access mandate likely enhances competition if imposed ex post on existing journals but may have the ex ante effect of curtailing entry.

## II. RELATED LITERATURE

Our paper is most closely related to several previous studies of the market for academic journals using two-sided-market models: Jeon and Rochet [2010], Armstrong [2015], and our own previous work (McCabe and Snyder [2005] and McCabe and Snyder [2007]).<sup>8</sup> While the present paper makes

<sup>7</sup>The competitive bottleneck can arise in the absence of the commitment problem, but only if authors care little about journal readership, say because citers can access the article through other channels. Then subscription fees can remain high under competition because authors do not demand low ones. Such a model could explain the low submission and high subscription fees documented in Table I for commercial journals. However, the model would leave no particular role for open access.

<sup>8</sup>See McCabe, Snyder, and Fagin [2014] for a survey. Several papers (McCabe [2004], Jeon and Menicucci [2006], Armstrong [2009]) provide theoretical analyses of the market for academic journals using a one-sided-market model, which

improvements along some dimensions, the contributions made by these earlier analyses continue to provide the state of the art along other dimensions. The present paper abstracts from article and journal quality, a key element of McCabe and Snyder [2005], McCabe and Snyder [2007], and Jeon and Rochet [2010]. Armstrong [2015] makes a number of important contributions, including providing a rich discussion of the economics of the journal market and the pros and cons of alternative open-access policies as well as analyzing two theoretical models, one about article dissemination and the other about certification. His analysis points to the advantages of a partial open-access regime (involving open access to an inferior version of the published work, say a self-archived pre-print, or after an embargo period), which can expand access without sharply increasing author fees and consequent deadweight loss. Our finding that an open-access mandate can be severely harmful to welfare is much in accord with his conclusions. The present paper adds to this literature by introducing novel assumptions about the timing of price setting and commitment, capturing what we think captures a key difference between traditional and open-access journals. Another contribution is that we embrace all the intricacies of the two-sided-market model. McCabe and Snyder [2005] and Jeon and Rochet [2010] abstract from deadweight loss on the author side two-sided-market model by assuming homogeneous authors, biasing the welfare calculation in favor of open access. McCabe and Snyder [2007] assume authors are charged a per-reader submission fee. Not only is this simplifying assumption counterfactual—submission fees are in fact lump-sum—it effectively solves the hold-up problem between journals and authors that is the substance of the present paper.<sup>9</sup> Armstrong [2015] eliminates the externality flowing from readers to authors by assuming that authors care about cites rather than readers. Under the further assumption that all citers have open access to articles via some channel—“green” open access if not “gold” using the definitions in footnote 4—cites become invariant to subscription prices.

Our paper is part of a much larger theoretical literature on two-sided markets as applied to such markets as telecommunications, payment-card systems, and media.<sup>10</sup> Of these, the closest is Hagiu [2009], one of the first papers to focus on the role of price commitments in two-sided markets. Hagiu [2009] assumes that the platform has no ability to commit to the price charged to later-arriving consumers, and so the developers’ earlier decision to participate in the platform is subject to the same hold-up problem as authors’ submission decision in our paper. The solution is different. In Hagiu [2009], the two sides of the market transact directly (developers sell games to consumers) with the platform extracting surplus via royalties. The platform can mitigate the hold-up problem by charging a high royalty fee because this induces it later to charge a low platform fee to increase the quantity demanded by buyers (the tradeoff is that the developers’ incentives to invest in noncontractible quality is reduced by a high royalty). In our paper, the two sides do not transact directly, and so there are no royalty payments. The platform considers mitigating hold up using the

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is not amenable to analyzing open-access questions. The opposite tack is taken by Jeon and Menicucci [2011]. In their bird’s-eye view of the market for academic journals, the platform is a website serving bundles of journals. They study the conditions under which various publishers’ websites interconnect, facilitating text-and-data-mining services and linking.

<sup>9</sup>Wright [2003] illustrates this point with an example from the credit-card market.

<sup>10</sup>The literature on two-sided markets is too large to survey here. See Rochet and Tirole [2006] for references to the literature prior to their paper. More recent work on two-sided markets includes Ambrus and Argenziano [2009], Halaburda and Yehezkel [2013], and Jullien [2011], in addition to the other papers referenced in this section.

Much of the applied work on two-sided markets, our paper included, builds on the foundation laid by the general analyses in Armstrong [2006] and Rochet and Tirole [2006]. In addition to a wealth of other cases, these seminal articles provide a thorough analysis of the case relevant to our setting, that of singlehoming on one side of the market and multihoming on the other side—with academic journals, authors can submit a single article only to one journal (singlehoming) while readers can subscribe to multiple journals simultaneously (multihoming). Among other similarities, by design, our Lerner-index formulas echo these general analyses’. Our paper contributes the new commitment assumption and the analysis of open access, mandates, and other policies specific to the journal application.

crude commitment to open access.<sup>11</sup>

Our paper has broader connections to several other literatures. The literature on consumer switching costs (see Klemperer [1987] for a seminal paper and Farrell and Klemperer [2007] for a review) finds competition can lead to a pattern of “bargains then rip offs” in two-period models because firms are unable to commit not to “rip off” locked-in consumers. This is reminiscent of our finding that competition among traditional journals reduces author prices down to a binding (zero-price or zero-profit) constraint, leaving the reader prices set later at the monopoly level. First-stage consumers in our setting (authors) do not directly suffer from the rip off but only indirectly through the downward distortion in readership. Farrell and Klemperer [2007] (footnote 25) note that a non-negativity constraint on prices in the bargain stage can prevent Bertrand competition from dissipating profits earned in the rip-off stage; for the same reasons, competing traditional journals can remain profitable in our setting. In the literature on net-neutrality regulation (e.g., Choi and Kim [2010] and Economides and Hermalin [2011]), the policy can be thought of as a crude commitment by an internet service provider not to discriminate over the prices it charges upstream content providers, analogous to the crude open-access commitment made by journals to authors in our setting.

### III. MODEL

The model has three types of economic agents: authors, readers, and journals. The representative author writes a single article. For every person who reads his or her article, the author obtains benefit  $v_a$ , embodying the pure psychic benefit from being read as well as the increase in prestige from having more readers know about and cite the article (more prestige leading to better chances of tenure, promotion, outside offers, and other career prospects). On the other side of the market, a representative reader obtains benefit  $v_r$  from each article read. Benefits  $v_i$ ,  $i \in \{a, r\}$ , are continuous random variables with density  $f_i$  on support  $[0, \bar{v}_i]$ , where  $\bar{v}_i > 0$  is allowed to be infinite. Assume throughout the analysis that  $f_i$  is differentiable and logconcave.<sup>12</sup> In some propositions, we will add the assumption that  $f_i$  is nonincreasing.<sup>13</sup> Let  $F_i(v_i) = \int_0^{v_i} f_i(x) dx$  be the associated distribution function and  $\bar{F}_i(v_i) = 1 - F_i(v_i) = \int_{v_i}^{\bar{v}_i} f_i(x) dx$  be its complement, also called the survivor function. The assumed conditions on  $f_i$  ensure  $F_i$  and  $\bar{F}_i$  are logconcave.<sup>14</sup> The distribution of  $v_i$  is common knowledge, but the specific value is private information for the individual.

<sup>11</sup>An earlier paper by the same author, Hagiu [2006], also studies price commitments in a two-sided market. Their role is quite different than in our paper. Price commitments have a drawback in Hagiu [2006]: although the platform can perfectly commit to prices, it cannot commit to quality because buyers’ value depends on the variety of seller offerings. Sellers may coordinate on an equilibrium in which few of them participate, leading to the self-fulfilling outcome in which few buyers purchase at the committed price. The absence of a price commitment breaks such inefficient coordination equilibria by letting the platform tailor the buyer price to the number of sellers who participate. Inefficient coordination equilibria do not arise in our setting because our authors are heterogeneous. Thus a perfect price commitment would always be beneficial if it were available, but because of contractual incompleteness, only crude commitments are available.

<sup>12</sup>For a discussion of logconcave distributions, see Bagnoli and Bergstrom [2005], who show that most distributions commonly used in economics have this property.

<sup>13</sup>The class of random variables with differentiable, nonincreasing, logconcave densities is fairly broad, including the uniform, exponential, half normal, half logistic, half extreme value, and beta  $\beta(a, b)$  for parameters  $a = 1$  and  $b \geq 1$ . That these densities are differentiable and nonincreasing can be verified by direct differentiation. It is then immediate from Corollary 1 of Bagnoli and Bergstrom [2005] that their *distribution* functions are logconcave. To show their *density* functions are logconcave takes a bit more work. The uniform, exponential, and beta densities are logconcave by Table 1 of Bagnoli and Bergstrom. A half-normal random variable is given by  $Y = |X|$ , where  $X$  is distributed  $N(0, \sigma^2)$ . Since  $X$  is normal, it is logconcave by Table 1 of Bagnoli and Bergstrom. Since  $Y$  is a truncation of logconcave  $X$ ,  $Y$  is logconcave by Theorem 9 of Bagnoli and Bergstrom. Similar logic can be applied to the half-logistic and half-extreme-value densities.

<sup>14</sup>An [1998] argues that a differentiable, logconcave function is continuously differentiable. Thus  $f_i$  satisfies the sufficient conditions in Bagnoli and Bergstrom’s [2005] Theorem 1 for  $F_i$  to be logconcave and in their Theorem 3 for  $\bar{F}_i$  to be logconcave.

A journal serves as an intermediary between authors and readers. Processing an article costs the journal  $c_a > 0$ , reflecting the effort involved in refereeing, copy editing, and typesetting—so-called “first copy” costs. Distributing an article to a reader costs  $c_r \geq 0$ , reflecting printing and shipping costs as well as the cost of servicing the reader’s account. While the inequality was likely strict in the era of print distribution, the weak inequality allows for the possibility that digital distribution has essentially eliminated reader costs.

Though each discipline is served by many journals, this may understate true concentration in markets segmented by subfield and prestige. We will capture potential market power in a simple model of a monopoly journal (deferring an analysis of competition to Section V). Concerning prestige, an author’s benefit from publishing in a higher ranked journal, thereby certifying the article meets a higher quality threshold, could be huge—arguably worth tens if not hundreds of thousands of dollars—overwhelming any practical differences in the journal’s readership or submission fees. To focus the analysis on these latter issues, we need to hold certification benefits constant. We do this by assuming the journal is of a given, known quality, as are articles.

We assume, consistent with industry practice, that authors cannot make direct payments to readers and vice versa, so that the benefits authors provide readers and vice versa are externalities. This feature makes academic journals a classic example of a two-sided market (Rochet and Tirole 2006). In a two-sided market, how total fees are divided across the two sides of the market will matter in equilibrium because their inability to make direct payments to each other eliminates their ability to pass the fees through.

The basic model considers a profit-maximizing journal. It charges submission fee  $p_a$  to authors and subscription fee  $p_r$  to readers. Following industry practice,  $p_a$  is a lump-sum fee, not variable conditioned on the number of subscribers the journal ends up having or on some imagined “pay per click” scheme. Also following industry practice, we constrain  $p_a, p_r \geq 0$ . Journals may subsidize authors and readers in setting prices below marginal cost but cannot make explicit cash transfers to them.<sup>15</sup>

The model has four stages. First, the journal sets  $p_a$ . Second, authors make submission decisions. Third, the journal sets  $p_r$ . Fourth, readers make their subscription decisions. We will solve for the subgame perfect equilibrium of this sequential game using backward induction.

A journal can choose between different modes of operation, which differ in the ability to commit to prices they set in later stages. A traditional journal cannot commit in the first stage to the reader price it will set in the third stage. Contractual incompleteness prevents future subscription fees from being part of the contract the journal signs with authors. We will allow a limited amount of commitment to reader fees. A journal can declare itself to be open access, committing to zero reader fees in the future. This crude commitment is the journal’s only available commitment mechanism. The traditional journal, which reserves the right to charge positive reader fees, cannot commit to the exact level this positive fee takes.

McCabe and Snyder [2015] offer evidence that the relevant commitment period for this market is on the order of decades, not years. If an article received most of its cites the year it is published, then the author might just be concerned with the current number of readers, a function of the current subscription fee. In fact most cites come many years after publication. Figure 1 from McCabe and Snyder [2015], estimated using a panel of cites to the over 260,000 articles published in the top 100 economics journals over five decades, shows the profile of the cites an article receives each year as it ages. The profile is hump-shaped, with yearly cites increasing sharply up to a peak five years after publication, declining gradually after that. Cumulating the results shown in the

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<sup>15</sup>The restriction of cash transfers appears to be nearly universal among scholarly journals. We impose the constraint exogenously, but it might be endogenized in a model in which the journal attempts to guard against corruption for example or to avoid an adversely selected pool of submissions from authors motivated by profit rather than prestige.

figure, one can calculate that more than 80% of the total cites an economics article receives over its lifespan come more than five years after publication. We are aware of no traditional journal that has committed to a subscription fees beyond the current year, to say nothing of five years and beyond. For large commercial publishers, perhaps the greatest obstacle to commitment is that they negotiate with individual institutions over subscription prices for bundles of journals (discussed further in Section V(ii)). Thousands of individual, secret negotiations are simply incompatible with commitment.<sup>16</sup>

While committing to a finely calibrated path of positive future fees may be infeasible, open-access journals have several ways to maintain the cruder commitment to zero subscription fees in the future. First, renegeing on the open-access commitment could be construed as fraud, leading to court enforcement. Monitoring violations of this bright-line policy, and thus enforcement on behalf of authors, would be relatively easy.<sup>17</sup> Even if courts did not directly involve themselves in enforcement, they could refrain from enforcing the journal’s copyright,<sup>18</sup> allowing authors and libraries to post the articles for free when the journal reneges on its open-access commitment. The most direct commitment mechanism is for the journal to grant authors rights to freely repost the article in the original publication agreement.<sup>19</sup>

#### IV. MONOPOLY JOURNAL

This section presents a detailed analysis of the case of a monopoly journal, providing the core results of the paper. As a benchmark, the first subsection analyzes equilibrium when the journal can fully commit to the sequence of author and reader prices. Subsequent subsections relax the full-commitment assumption, analyzing equilibrium first with a traditional and then with an open-access journal. Most of the core results come in the final subsections, which are devoted to comparing equilibria under various modes of journal operation.

##### IV(i). *Full Commitment*

We begin by analyzing the case in which the monopoly journal can commit to the full vector  $(p_a, p_r)$  at the outset of the game. This analysis serves two purposes. First, while journals may not have full commitment power in the current era of digital journals, an analysis of full commitment provides a benchmark to help gauge how a lack of commitment contributes to the current situation. Second, journals may have had power to commit to subscription fees in practice during the previous era of print journals. Rather than renting access via a journal’s website, in that era libraries acquired the physical copy of a volume, affording its patrons permanent access. The subscription fee charged when an article was submitted thus provided some indication of the article’s future accessibility.

<sup>16</sup>Perhaps the strongest support for our commitment assumption is provided by an anecdote about the Berkeley Electronic Press (bepress) journals. These for-profit journals were founded on a number of principles including “fast turnaround times . . . and a commitment to sustainable prices for libraries” (quoted from the website, “The bepress mission,” [www.bepress.com/aboutbepress.html](http://www.bepress.com/aboutbepress.html), accessed April 6, 2015). Although these journals never declared themselves to be open access, they did allow free access to individuals willing to fill out a form. After the sale of bepress journals to De Gruyter in 2011, individual access was restricted, requiring a yearly subscription fee of \$149 per title for individuals (or between \$400–\$600 per title for institutional subscriptions). The commitment to “sustainable” prices was evidently not equivalent to the commitment to open access.

<sup>17</sup>For a discussion of the advantages of bright-line rules in an environment with weak property rights, see Hay and Shleifer [1998].

<sup>18</sup>Shavell [2010] advocates nullifying journals’ copyright to academic articles as an alternative to open access.

<sup>19</sup>Examining the wave of nearly 1,000 delisted by the DOAJ in 2014, 50 were delisted because they switched from open to traditional access. The random sample we checked all maintained open access to the articles published before the access switch.



Analyzing the commitment case will provide predictions about the effect of the move from print to digital that can be checked against market facts.

To solve for equilibrium prices, we need an expression for the journal's profit from an arbitrary price vector  $(p_a, p_r)$ . The journal's profit depends on author and reader demands, for which we can solve working backward from the end of the game in order to take into account players' rational expectations. Considering the representative reader's subscription decision in the last stage of the game, his surplus from subscribing to a journal that has received a submission and thus has nontrivial content is  $v_r - p_r$ . He subscribes if  $v_r > p_r$  and not if  $v_r < p_r$ , implying that reader demand, denoted  $Q_r(p_r)$ , is given by  $Q_r(p_r) = \bar{F}_r(p_r)$ . Let  $\pi_r(p_r) = (p_r - c_r)Q_r(p_r)$  be the expected continuation profit from serving the reader side.

Folding the game back to the representative author's submission decision, given he rationally expects to have  $Q_r(p_r)$  readers, his expected net surplus is  $v_a Q_r(p_r) - p_a$  from submitting a paper. He thus submits if  $v_a > p_a / Q_r(p_r)$ . Letting  $Q_a(p_a, p_r)$  denote the probability the author submits—equivalent to the expected number of articles in the journal—we have  $Q_a(p_a, p_r) = \bar{F}_a(p_a / \bar{F}_r(p_r))$ . Conditional on receiving a submission, the journal earns total stream of profit  $p_a - c_a + \pi_r(p_r)$  from both author and reader sides. Multiplying by the probability of submission yields the desired expression for ex ante expected journal profit:

$$(1) \quad \Pi(p_a, p_r) = [p_a - c_a + \pi_r(p_r)]Q_a(p_a, p_r).$$

A journal with full commitment is able to set both fees to maximize this profit:

$$(2) \quad (p_a^{mf}, p_r^{mf}) = \operatorname{argmax}_{p_a, p_r \geq 0} \Pi(p_a, p_r).$$

The notational convention throughout the paper will be that superscripts indicate equilibrium values of variables; the particular superscript  $mf$  here indicates equilibrium values in the monopoly, full-commitment case. The optimal fees solve the system of two first-order conditions. Rearranging the first-order condition with respect to  $p_a$  yields the Lerner index formula for the submission fee,

$$(3) \quad L_a^{mf} = \frac{p_a^{mf} - c_a}{p_a^{mf}} = \frac{1}{|\eta_a^{mf}|} - \frac{\pi_r^{mf}}{p_a^{mf}},$$

where  $\eta_a^{mf} = \frac{\partial}{\partial p_a} Q_a(p_a^{mf}, p_r^{mf}) p_a^{mf} / q_a^{mf} = -f_a(p_a^{mf} / q_r^{mf}) p_a^{mf} / q_a^{mf} q_r^{mf}$  is the own-price elasticity of author demand,  $q_a^{mf} = Q_a(p_a^{mf}, p_r^{mf})$  and  $q_r^{mf} = Q_r(p_r^{mf})$  are equilibrium author and reader quantities, and  $\pi_r^{mf} = \pi_r(p_r^{mf})$  is equilibrium continuation profit from readers. The Lerner index formula in (3) holds for an interior solution ( $p_a^{mf} > 0$ ) to (2). Otherwise, we simply have the corner solution  $p_a^{mf} = 0$ .<sup>20</sup> The Lerner index in (3) is lower than the standard inverse elasticity rule for a monopolist by the term  $\pi_r^{mf} / p_a^{mf}$ , reflecting the extra profit earned from the reader side of the market from signing up an author. Indeed, this Lerner index can be negative, in which case the author margin would be negative (i.e.,  $p_a^{mf} < c_a$ ).

Taking the first-order condition of (2) with respect to  $p_r$ , substituting from the first-order condition behind (3), and rearranging yields the Lerner index formula for the subscription fee,

$$(4) \quad L_r^{mf} = \frac{p_r^{mf} - c_r}{p_r^{mf}} = \frac{1}{|\eta_r^{mf}|} - \frac{p_a^{mf}}{p_r^{mf} q_r^{mf}},$$

<sup>20</sup>A sufficient condition for the solution to be interior is that profit from the reader side not be so large that it overwhelms the incentive to extract revenue from authors: i.e.,  $\pi_r^{mf} < c_a$ . Another sufficient condition is  $f_a(0) = 0$ .

where  $\eta_r^{mf} = Q'_r(p_r^{mf})p_r^{mf}/q_r^{mf} = -f_r(p_r^{mf})p_r^{mf}/q_r^{mf}$  is the price elasticity of reader demand. Again, the Lerner index is lower than the standard inverse elasticity rule, here reflecting the extra revenue paid by authors when there are more readers. Again, this Lerner index and the associated reader margin can be negative.

Denote the journal's equilibrium profit under full commitment by  $\Pi^{mf} = \Pi(p_a^{mf}, p_r^{mf})$ . Social welfare for an arbitrary price vector  $(p_a, p_r)$  can be expressed as the gross consumer surplus from both sides of the market less the total cost of serving both sides:

$$(5) \quad SW(p_a, p_r) = \int_{p_a/Q_r(p_r)}^{\bar{v}_a} \int_{p_r}^{\bar{v}_r} (v_a + v_r) f_a(v_a) f_r(v_r) dv_a dv_r - [c_a + c_r Q_r(p_r)] Q_a(p_a, p_r).$$

Equilibrium social welfare under full commitment then is  $SW^{mf} = SW(p_a^{mf}, p_r^{mf})$ .

#### IV(ii). *Traditional Journal*

Next consider a monopoly traditional journal, which cannot commit to a subscription fee. Suppose the journal obtained a submission in the second stage. Unable to commit to  $p_r$  before, in the third stage the journal chooses  $p_r$  to maximize its expected continuation profit:

$$(6) \quad p_r^{mt} = \operatorname{argmax}_{p_r \geq 0} \pi_r(p_r),$$

the standard monopoly price treating the reader side as a stand-alone market. Let  $\pi_r^{mt} = \pi_r(p_r^{mt})$ . The maximization problem behind (6) has a nontrivial interior solution if and only if  $\bar{v}_r > c_r$ , in which case  $\pi_r^{mt} > 0$ .

Rearranging the first-order condition associated with (6) yields the Lerner index formula

$$(7) \quad L_r^{mt} = \frac{p_r^{mt} - c_r}{p_r^{mt}} = \frac{1}{|\eta_r^{mt}|},$$

where  $\eta_r^{mt} = Q'_r(p_r^{mt})p_r^{mt}/q_r^{mt}$  is the reader-demand elasticity and  $q_r^{mt} = Q_r(p_r^{mt})$  reader quantity. These variables have similar definitions to their analogs in the previous subsection but are evaluated at the prices relevant to this equilibrium. Equation (7) is the standard inverse elasticity rule for monopoly markups. In contrast to the analogous Lerner index (4) from the full-commitment case, (7) does not include a term reflecting the externality on the author side because author demand is sunk by the time  $p_r^{mt}$  is chosen.

Folding the game back to the first stage, the journal chooses the submission fee to maximize profit from all stages:

$$(8) \quad p_a^{mt} = \operatorname{argmax}_{p_a \geq 0} \Pi(p_a, p_r^{mt}) = \operatorname{argmax}_{p_a \geq 0} (p_a - c_a + \pi_r^{mt}) \bar{F}_a(p_a/q_r^{mt}).$$

Rearranging the first-order condition associated with (8) yields the Lerner index formula

$$(9) \quad L_a^{mt} = \frac{p_a^{mt} - c_a}{p_a^{mt}} = \frac{1}{|\eta_a^{mt}|} - \frac{\pi_r^{mt}}{p_a^{mt}},$$

where  $\eta_a^{mt} = \frac{\partial}{\partial p_a} Q_a(p_a^{mt}, p_r^{mt}) p_a^{mt} / q_a^{mt}$  and  $q_a^{mt} = Q_a(p_a^{mt}, p_r^{mt})$ . The formula in (9) holds when (8) has an interior solution (i.e.,  $p_a^{mt} > 0$ ). Otherwise the solution is simply the corner  $p_a^{mt} = 0$ . Equation (9) has the same form as the Lerner index formula (3) in the full-commitment case. The only difference

is that it is evaluated at a potentially different level of reader profit,  $\pi_r^{mt}$  rather than  $\pi_r^{mf}$ .

For later reference, let  $\Pi^{mt} = \Pi(p_a^{mt}, p_r^{mt})$  denote profit and  $SW^{mt} = SW(p_a^{mt}, p_r^{mt})$  denote social welfare in equilibrium with a traditional journal.

#### IV(iii). *Open-Access Journal*

Next we turn to the case of a monopoly open-access journal, which makes the crude commitment ex ante to charge zero subscription fees ex post. Since its equilibrium subscription fee is  $p_r^{mo} = 0$  by definition, we need only solve for its equilibrium submission fee:

$$(10) \quad p_a^{mo} = \underset{p_a \geq 0}{\operatorname{argmax}} \Pi(p_a, 0) = \underset{p_a \geq 0}{\operatorname{argmax}} (p_a - c_a - c_r) \bar{F}_a(p_a).$$

The expression reflects the cost of serving the reader as well as the author but no revenue from readers.

Rearranging the first-order condition associated with (10) yields the Lerner index formula

$$(11) \quad L_a^{mo} = \frac{p_a^{mo} - c_a}{p_a^{mo}} = \frac{1}{|\eta_a^{mo}|} + \frac{c_r}{p_a^{mo}}.$$

where  $\eta_a^{mo} = \frac{\partial}{\partial p_a} Q_a(p_a^{mo}, 0) p_a^{mo} / q_a^{mo}$  and  $q_a^{mo} = Q_a(p_a^{mo}, 0)$ . Equation (11) implies that the open-access journal sets a higher price than implied by the inverse elasticity rule for a standard monopolist. The journal recognizes that publishing an article invariably generates a reader, who is costly to serve but provides no revenue. This ex post loss leads the journal to shade the submission fee up. If  $c_r = 0$ , then the journal's markup is exactly given by the standard inverse elasticity rule. An open-access journal is profitable if and only if  $p_a^{mo} > c_a + c_r$ . Hence a profitable open-access journal will necessarily have positive author margins: i.e.,  $p_a^{mo} > c_a$ .

For later reference, let  $\Pi^{mo} = \Pi(p_a^{mo}, p_r^{mo}) = \Pi(p_a^{mo}, 0)$  denote profit and  $SW^{mo} = SW(p_a^{mo}, 0)$  denote social welfare in equilibrium with an open-access journal.

#### IV(iv). *Comparing Traditional and Open-Access Journals*

Having solved for monopoly equilibrium under a traditional and open-access journal, we turn to a comparison of prices, profits, and social welfare across the two modes of operation.

Start with a comparison of prices. Obviously, the equilibrium subscription fee is weakly lower for an open-access than for a traditional journal, as the subscription fee under open access is the lowest possible non-negative price, 0. The comparison of submission fees is more complicated. The industrial-organization literature has long recognized that perverse cases can arise—in which an exogenous increase in quality leads to a fall in the monopoly price—unless restrictions are placed on higher-order derivatives (Levhari and Peles 1973, p. 243). The same is true here taking submission to be the good purchased by authors, open-access submission being the high-quality product (because of greater readership) and traditional being the low-quality product. It turns out that the assumed logconcavity of  $f_a$  is sufficient to guarantee the monopoly open-access journal charges a higher submission fees than the traditional journal.<sup>21</sup> The following proposition, proved in Appendix B, summarizes our results from our comparison of prices.

<sup>21</sup>The proof of Proposition 1 provides a counterexample having non-logconcave  $f_a$  in which the ranking of equilibrium submission fees is reversed, i.e.,  $p_a^{mo} < p_a^{mt}$ .

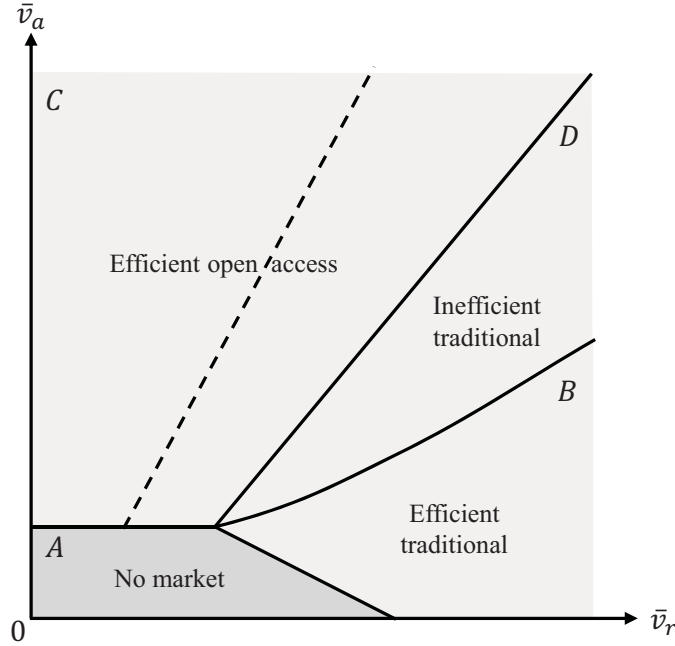


Figure 1  
Monopoly Outcomes in Numerical Example

Notes: Example involves  $c_a = 1/2$ ,  $c_r = 0$ ,  $v_a$  uniformly distributed on  $[0, \bar{v}_a]$ , and  $v_r$  uniformly distributed on  $[0, \bar{v}_r]$ , for various values of  $\bar{v}_r$  and  $\bar{v}_a$ . The socially efficient outcome refers to the social planner's preferred mode of operation when pricing is delegated to the monopoly journal.

**Proposition 1.** *A monopoly open-access journal has a weakly lower subscription fee than a traditional journal:  $p_r^{mo} = 0 \leq p_r^{tr}$ . Assume both types of journal earn positive profit. Then the open-access journal has a higher submission fee than the traditional journal:  $p_a^{mo} > p_a^{tr}$ .*

Next turn to a comparison of profits, which will help us determine which mode the journal chooses in equilibrium, and a comparison of social welfare, which will help us determine whether the equilibrium choice is efficient. To better understand the variety of cases that will emerge, consider Figure 1, which presents results for a numerical example with uniformly distributed values, varying the upper bounds on the distributions' supports, with  $\bar{v}_r$  on the horizontal axis and  $\bar{v}_a$  on the vertical axis. All the highlighted results from the figure will turn out to hold more generally as will be verified in a series of propositions interspersed throughout the discussion.

In region A neighboring the origin, author and reader values are too low for the journal to be able to cover its costs and earn a positive profit regardless of its mode of operation. In effect, the journal market disappears in this region.

The journal market is nontrivial in the figure's remaining regions. In the southeast region of the figure labeled B, characterized by relatively high reader and low author values, we see the possibility documented that traditional can be more profitable than open access. This is no surprise. If reader values dominate author values, the journal takes the opportunity to extract revenue from the reader side using a positive subscription fee. What may be surprising is that a monopoly traditional journal can be socially more efficient than a monopoly open-access journal, another possibility documented in region B. The intuition behind this possibility is that, when reader values dominate author values, social welfare hinges on providing the high-value readers with as many articles to read as possible.

A traditional journal does exactly that in the limit as  $\bar{v}_r \rightarrow \infty$ , because then  $p_a^{mt} \rightarrow 0$ , inducing all author types to submit, with the journal earning all its profit from the reader side. By contrast, to earn a profit, an open-access journal must charge a submission fee above  $c_a + c_r$  and thus bounded away from 0, resulting in a downward distortion in submissions. Indeed,  $q_a^{mo} \rightarrow 0$  in the limit  $\bar{v}_a \rightarrow 0$ .

The northwest region labeled  $C$  is characterized by relatively high author and low reader values. In this region, we see the possibility documented that open access can be more profitable than traditional. Although open access “throws away” profit from the reader side of the market, the journal may still choose this mode of operation because it benefits from the commitment to expanded readership, enabling the journal to extract more revenue from the author side. This logic suggests that the journal should find open access relatively more attractive when author values dominate reader values, and indeed region  $C$  is characterized by this relationship between values. Open access is not only the privately efficient choice but also the socially efficient choice in this region. Intuitively, social welfare improves when the extremely high-value authors in the limit have as many readers as possible, which open access facilitates.

The next proposition, proved in Appendix B, generalizes the observations from the last two paragraphs beyond the numerical example. The statement of the proposition introduces some additional notation, which needs some explanation. The limits referred to in the previous paragraph involved shifting upper bounds  $\bar{v}_a$  and  $\bar{v}_r$  on the value distributions. This is how scale transformations are accomplished with the uniform distributions underlying the numerical example. To accomplish scale transformations for general distributions, and to allow values to grow on one side at the same time they shrink on the other, we scale author values in proportion and reader values in inverse proportion to scale factor  $\alpha > 0$ , interpreted as the relative importance of the author side.

**Proposition 2.** *Consider rescaled author values  $\omega_a = \alpha v_a$  and rescaled reader values  $\omega_r = v_r/\alpha$  for  $\alpha \in [0, \infty)$ . The monopoly journal chooses traditional access, and this choice is socially efficient, in the limit  $\alpha \rightarrow 0$ . It chooses open access, and this choice is socially efficient, in the limit  $\alpha \rightarrow \infty$ .*

In the remaining region,  $D$ , the journal makes one choice in equilibrium (traditional) but social welfare would have been higher if it chose the alternative (open access). The region thus documents the possibility of socially excessive traditional access. Notice there is no complementary region exhibiting socially excessive open access. Thus, in this numerical example at least, the planner has a bias relative to the monopolist toward open access. Why? Returning to the interpretation of different modes of access as different qualities of product sold to authors, the clear direction of bias here may surprise the reader familiar with the well-known result from Spence [1975] that a monopolist, who cares about the marginal consumer’s valuation of quality, may choose any level of quality—higher, lower, or the same—as a planner, who cares about the average consumer’s valuation. An added factor here biasing the planner toward open access is that open access is a special sort of quality, generating consumer surplus for readers on the other side of the market, a benefit internalized by the planner but not the journal. For the more standard products in Spence [1975], quality has no associated two-sided-market externality. The next proposition generalizes the planner’s bias toward open access beyond the uniform distribution of the numerical example.

**Proposition 3.** *Suppose that, in addition to being logconcave, densities  $f_a$  and  $f_r$  are nonincreasing. If the monopoly journal chooses open access in equilibrium, this choice is also socially efficient. On the other hand, cases can be constructed in which the monopoly journal chooses traditional access when social welfare would have been higher if it chose open access.*

We conjecture that the result may hold for all logconcave densities but have only succeeded in generalizing it to nonincreasing ones in the proof, provided in Appendix B. <sup>22</sup>

<sup>22</sup>The proof of the first claim of Proposition 3 is fairly involved. We use a worst-case analysis, searching over nonincreas-

To summarize, the results in this subsection accord with standard intuition from the two-sided-markets literature. The standard intuition is that it is privately and socially efficient to nurture, either through low prices or subsidies, not the important (i.e., high-value) side of the market, but the opposite side because of the large benefit the important side obtains from an increase in participation on the opposite side.<sup>23</sup> We see this in our journals setting. When the reader side is sufficiently more important, traditional access, entailing relatively low author and high reader prices, is privately and socially optimal. When the author side is sufficiently more important, open access, entailing high author and low (zero) reader prices, is privately and socially optimal. While this intuition accord with the two-sided-markets literature, it is less commonly understood by commentators, who, when advocating for open access, point to the reader side without reference to the author side.<sup>24</sup> We find that distortion is likeliest when the author and reader sides are of roughly the same importance. To overcome the excess traditional access arising in this case, policies supporting open access may be justified.

The propositions contribute to an understanding of the recent rise of “megajournals,” open-access journals that publish huge numbers of articles according to a refereeing standard judging articles according to methodological soundness rather than importance or impact. This is the niche in which commercial publishers have shown the most activity in open-access publishing, including *Nature*, with its Scientific Reports and Hindawi Publishing with its *Scientific World Journal*. The largest megajournal—the largest journal in the world in fact—is *PLOS One* (Binfield 2003), its team of over 6,000 editors publishing over 30,000 articles in 2013.<sup>25</sup> The publication standards at megajournals are dramatically lower than the flagship journals at these same publishers: for example, *PLOS One* had an acceptance rate of 70% (Curry 2012) compared to less than 10% at *PLOS Biology* (Varmus 2009, p. 264). Articles only meeting a vanishingly low quality standard may not provide much reader benefit. This is exactly the case in which Proposition 2 guarantees a commercial journal prefers open to traditional access. Unable to earn much revenue from readers, the journal instead generates revenue from the author side. Besides explaining why megajournals are open access, the proposition provides normative support for the social efficiency of their operating this way.

#### IV(v). *Comparing Crude to Full Commitment*

This subsection explores the role of our commitment assumption by comparing the equilibrium under crude commitment to that under full commitment. Our underlying motivation for introducing the crude-commitment assumption, besides realism, was to provide a broad rationale for open access. Thus it should be no surprise that our comparative-statics exercise will show that moving from crude to full commitment reduces open access. Indeed, we will prove that the reduction is strict in general, and document that the reduction can be quite dramatic in numerical examples. The intuition for why

ing, logconcave densities for the  $f_a$  and  $f_r$ , minimizing  $SW^{mo} - SW^{mt}$  subject to the constraint  $\Pi^{mo} \geq \Pi^{mt}$ . This turns out to be a complex optimal-control problem having a corner solution provided by uniform distributions. Given these functional forms, the problem can be translated into a standard constrained minimization problem, which after solving numerically, yields a minimum value of 0 for  $SW^{mo} - SW^{mt}$ , proving  $SW^{mt}$  cannot exceed  $SW^{mo}$  when  $\Pi^{mo} \geq \Pi^{mt}$ . The second claim of the proposition follows from the fact that region  $C$  is nonempty by inspection of Figure 1.

<sup>23</sup>See Section 3.6.1 of Farrell and Klemperer’s [2007] handbook chapter for a concise statement of these principles.

<sup>24</sup>For example, the 2001 Budapest Open Access Initiative, regarded as the birth of the open-access movement, states in the first paragraph of its Declaration: “Removing access barriers to this literature will accelerate research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge.” Downloaded March 16, 2017 from [www.budapestopenaccessinitiative.org/read](http://www.budapestopenaccessinitiative.org/read).

<sup>25</sup>*PLOS One* is published by a nonprofit, the Public Library of Science (PLOS), although if critics are correct in their claim that one of its objectives is to generate revenue to subsidize PLOS’s higher-impact journals (Butler 2008), the for-profit model may have some relevance.

increased commitment reduces open access is straightforward. Moving from crude to full commitment gives the journal more instruments to maximize profit. It can always mimic the operation of an open-access journal by setting a zero subscription fee, but it can often do better by committing to a small but positive subscription fee. Faced with the choice of two extreme subscription fees, either zero or the monopoly level, zero may be better, but better still may be a moderate subscription fee between these extremes if the journal is able to so commit.

To aid the formal discussion, we introduce some additional notation. Let  $(p_a^{mc}, p_r^{mc})$  denote the equilibrium price vector when the journal only has crude commitment power and chooses the more profitable mode of operation between traditional and open access. That is,  $(p_a^{mc}, p_r^{mc}) = (p_a^{mt}, p_r^{mt})$  when  $\Pi^{mt} > \Pi^{mo}$  and  $(p_a^{mc}, p_r^{mc}) = (p_a^{mo}, p_r^{mo})$  when  $\Pi^{mo} > \Pi^{mt}$ .<sup>26</sup> We will compare  $(p_a^{mc}, p_r^{mc})$  to the equilibrium price vector under full commitment,  $(p_a^{mf}, p_r^{mf})$ . The next proposition, proved in Appendix B, provides a formal statement of the claim that moving from crude to full commitment reduces open access.

**Proposition 4.** *If  $\Pi^{mt} > \Pi^{mo}$ , the equilibrium subscription fee is positive under both crude and full commitment ( $p_r^{mc}, p_r^{mf} > 0$ ). If  $\Pi^{mo} > \Pi^{mt}$ , access is always open under crude commitment ( $p_r^{mc} = 0$ ), but cases can be constructed in which access is not open under full commitment (i.e., in which  $p_r^{mf} > 0$ ).*

The content of this proposition can be visualized using Figure 1. In regions *B* and *D*, when the journal has crude commitment power, equilibrium involves traditional access, with a positive subscription fee  $p_r^{mc} = p_r^{mt} > 0$ . According to the first statement of the proposition, the subscription fee remains positive,  $p_r^{mf} > 0$ , if the journal gains full commitment power in these regions. Figure 1 provides the case needed to provide the second statement of the proposition. All of region *C* exhibits open access when the journal has crude commitment power. One can show that in the subregion of *C* between the dotted line and the boundary with *D*, the journal switches to a positive subscription fee when it gains full commitment power. To understand why, focus on the boundary between region *C* and *D*, the locus of parameters for which  $\Pi^{mt} = \Pi^{mo}$ , implying that the journal is indifferent between traditional and open access under crude commitment. Moving to full commitment does nothing to improve profit from open access—the journal is able to charge the profit-maximizing submission fee in any event—but increases the profit of a journal charging positive subscription fees—because it can commit to a lower, and more profitable, subscription fee than  $p_r^{mt}$ . Thus the move from crude to full commitment breaks the journal’s indifference along the bound between *C* and *D*, leading it to strictly prefer positive subscription fees. By continuity, in a neighborhood above this boundary the journal will switch from open access to positive subscription fees when the journal gains full commitment. In this particular numerical example, no small neighborhood but the large subregion of *C* between the dotted line and the boundary with *D* experiences the switch.

The previous proposition showed how the commitment assumption affects the extent of open access. We next analyze how the commitment assumption affects prices on both sides of the market change. Under our assumption of logconcave densities, the comparative-static effects of commitment on fees are sharp and intuitive. Commitment allows the journal to solve the hold-up problem. Since the hold-up problem involves subscription fees that are too high, its solution involves a reduction in subscription fees (unless zero to begin with). The submission fee rises because the author can be charged more for the higher quality product having more readers. Formally, we have the following proposition, proved in Appendix B.

<sup>26</sup>In the knife-edged case  $\Pi^{mt} = \Pi^{mo}$ , there are multiple equilibria, one with traditional and one with open access, in which case  $(p_a^{mc}, p_r^{mc})$  will be taken to be a set of equilibrium price vectors. The text following Proposition 4 discusses multiple equilibria further.

**Proposition 5.** *If the submission and subscription fees are positive in equilibrium under crude commitment ( $p_a^{mc}, p_r^{mc} > 0$ ), then the move to full commitment strictly increases submission fees ( $p_a^{mf} > p_a^{mc}$ ) and strictly decreases subscription fees ( $p_r^{mf} < p_r^{mc}$ ). If the journal offers free submission under full commitment ( $p_a^{mf} = 0$ ), then moving to crude commitment leaves fees and profits unchanged.*

## V. EXTENSIONS

This section provides a series of brief extensions to cases of practical interest in the journals market.

### V(i). *Nonprofit Journals*

The analysis so far has focused on for-profit journals. This section moves to an analysis of nonprofits, an important case to study because notable journals in a variety of subfields are in practice published by societies, universities, and other nonprofits. In economics, for example, the top five journals in Table I in the data appendix are all nonprofits. The complication in studying nonprofits is that their objective function is not uniquely determined unlike for-profits. It is still possible here to provide qualitative results that apply for a range of possible nonprofit objectives.

Determining the equilibrium fee structure for a non-profit journal is straightforward in the case in which it is an open-access journal. By definition of open access, its subscription fee must be 0. This leaves the submission fee. Whatever the nonprofit's objectives, it is unlikely it would be biased toward higher-than-monopoly prices. Therefore, it is natural to expect a nonprofit open-access journal would typically charge a weakly lower submission fee than a for-profit. How much lower depends on the specific objectives as well as the availability of external funds to subsidize operating deficits.<sup>27</sup>

The case of a nonprofit traditional journal raises additional economic considerations. Whereas a for-profit traditional journal cannot commit not to monopolize the reader side of the market with high subscription fees, nonprofit status can end up functioning as a commitment to low subscription fees. In the simple case in which the publisher has no other lines of business besides the journal, subscription fees above a certain level would generate profit, violating the publisher's nonprofit status. It is theoretically possible that a nonprofit journal could generate the first best, if it could credibly establish this objective and had a source of funds to subsidize losses if necessary.

Indeed, the traditional model may be a better model for some nonprofit journals, allowing a balance of low author and reader fees without constraining the reader fees to be exactly zero, which as will be shown in Section V(v) may not be efficient. This may explain why many nonprofits have not gone the open-access route. For example, none of the top nonprofit economics journals in Table I have. However, under some conditions, open-access can be optimal for the nonprofit, consistent with the policies of the economics journals discussed in footnote 27.

### V(ii). *Bundles of Journals*

As documented by McCabe [2004] and Bergstrom *et al.* [2014], many major commercial publishers have moved from posting list prices for individual journals to negotiating with subscribing insti-

<sup>27</sup>Of the six economics journals indexed by the Social Science Citation Index (SSCI) that are open access, five are published by non-profits. Only one of these five, the *South African Journal of Economics and Management Science*, charges a substantial author fee, a per-page fee ranging up to \$470 for an article. The two Econometric Society journals, *Theoretical Economics* and *Quantitative Economics*, only charge a \$75 submission fee, waived for members and reduced for authors from developing countries. The two remaining journals charge neither submission nor subscription fees, so must use external sources to support their operation.



tutions over a bundled price (so-called “big deals”) for large portfolios of the publisher’s journals. The bundles often involve deep discounts relative to the sum of list prices for the individual journal subscriptions. For example, Bergstrom *et al.* [2014] found that the average Research I University paid \$1.2 million for the complete bundle of Elsevier’s nearly 3,000 journals, a 60% discount on the \$3.1 million combined list price. Bundling was enabled by the move to digital journals, which reduced the cost of supplying extra digital journals to an institution almost to zero (more analysis of endogenous costs is provided in the next section). Bergstrom *et al.* [2014] note that publishers had good information about an institution’s willingness to pay when setting the bundle price: in addition to demographic factors such as number of faculty, students, endowment, etc., the publisher knew the journals to which institution previously subscribed at the posted prices.

We capture the essence of bundling in our model by assuming that bundling allows the publisher to extract all the reader’s surplus, in essence enabling first-degree price discrimination. While this undoubtedly overstates the quantitative impact of bundling, it is directionally correct regarding two important effects of bundling: bundling allowed the publisher to extract more revenue from rich institutions while continuing to serve lower-tier institutions at lower prices. Bergstrom *et al.* [2014] find that per-citation subscription fees for the bundles offered by Elsevier, Springer, and Wiley were multiples of the fees charged by nonprofits to Research I and II universities but about equal to the nonprofit fees for the next tier, Masters-granting institutions.

According to this model, a monopoly publisher that can bundle charges the reader  $p_r^{mb} = v_r$ , whom it serves if  $v_r \geq c_r$ . As discussed in the next section, it is reasonable to have in mind the case in which  $c_r$  is close to 0, so that most readers are served. Expected profit from the reader side is  $\pi_r^{mb} = \int_{c_r}^{\bar{v}_r} v_r f_r(v_r) dv_r > \pi_r^{mt}$ .

Folding the game back to the first stage, the publisher chooses  $p_a$  to maximize profit from all stages:

$$(12) \quad p_a^{mb} = \operatorname{argmax}_{p_a \geq 0} \left[ (p_a - c_a + \pi_r^{mb}) Q_a(p_a, c_r) \right].$$

This is similar to (8) except that the profit earned from the reader side is higher under bundling than for the traditional journal (first-degree price discrimination is more profitable than linear pricing by a monopolist); i.e.,  $\pi_r^{mt} < \pi_r^{mb}$ . Reader quantity is also higher under bundling, i.e.,  $q_r^{mt} = Q_r(p_r^{mt}) < Q_r(c_r) = q_r^{mb}$ . Rearranging the first-order condition from maximizing (12) yields the Lerner index formula

$$(13) \quad L_a^{mb} = \frac{p_a^{mb} - c_a}{p_a^{mb}} = \frac{1}{|\eta_a^{mb}|} - \frac{\pi_r^{mb}}{p_a^{mb}}.$$

where  $\eta_a^{mb} = \frac{\partial}{\partial p_a} Q_a(p_a^{mb}, c_r) p_a^{mb} / q_a^{mb}$ . The monopoly submission fee is shaded down even lower with bundling on the reader side because a submission generates even more reader profit. With lower submission fees, the nonnegativity constraint  $p_a^{mb} \geq 0$  is even more likely to bind, leading to free submission.

In the presence of bundling, the inability to commit to reader prices is much less of a problem for the monopoly publisher. The bundling publisher serves as many readers as it would under marginal-cost pricing.<sup>28</sup> Thus the publisher credibly serves a wide readership even without commitment power.

<sup>28</sup>It is not correct to say that bundling eliminates deadweight loss on the reader side because the first best involves below-marginal-cost pricing due to externalities across the two sides of the market.

### V(iii). *Hybrid Pricing*

In this subsection we analyze the hybrid strategy of allowing authors the option of traditional access at one fee or open access for an additional premium. Major publishers have instituted this pricing strategy. For example, Springer offers an open-access option for most of its journals for a premium of \$3,000; Elsevier's premium ranges up to \$5,000 and Wiley's up to \$5,200.

A hybrid journal can be modeled as follows. Continue to assume (as we had with traditional and open-access journals) that the journal's pricing strategy is exogenous at the start of the game and known to all players. A journal's first move is to set author prices. For a hybrid journal, this is a menu of two prices. We continue to let  $p_a$  represent the basic submission fee and introduce  $x_a$  as the premium which the author can choose to pay for open access. Thus, for an author who submits an article that will receive traditional access, the total price is  $p_a$ ; for an article that will receive open access, the total price is  $p_a + x_a$ .

A rigorous analysis of the equilibrium hybrid strategy becomes quite involved. For space considerations we relegate the full analysis to Appendix C. Here, we just highlight some of the results, which turn out to have intuitive appeal. A monopoly hybrid journal charges the same basic submission fee as a monopoly traditional journal:  $p_a^h = p_a^{mt}$  (where the  $h$  superscript indicates the hybrid case). The open-access premium  $x_a^h$  is set according to the principles of the Efficient Components Pricing Rule (ECPR) (Baumol and Sidak, 1994), reflecting a markup over standard marginal costs (here the cost of processing an article and delivering it to all readers,  $c_a + c_r$ ) and an additional opportunity cost of lost revenue from readers. The markup is set to effectively monopolize the segment of the author market with high values  $v_a$  of readership.

### V(iv). *Competing Journals*

For simplicity, the analysis has so far focused on the case of a monopoly journal. In this subsection, we expand the analysis to allow for competing journals. We will do this in two steps. First, we will derive the equilibrium for any exogenous market structures with whole numbers  $T$  of traditional journals and  $O$  of open-access journals. Then we allow for endogenous entry, culminating in an analysis of a free-entry model, i.e., the limit of a general endogenous-entry model in which journals' fixed entry costs are taken to zero. As free entry is the polar opposite of monopoly, an analysis of a free-entry model will help reinforce the main theme of this subsection: that the results derived in the baseline, monopoly case are robust across market structures.

We begin the analysis of competition by taking the number of traditional and open-access journals in the market as exogenous. To allow for multiple journals, we will modify the monopoly model introduced in Section III as follows. The journals choose submission fees simultaneously. Then the representative author decides which journal, if any, to submit to based on the submission fees and rational expectations about the future subscription fee and reader behavior. Then the journal that secured the submission sets its subscription fee, and readers choose to subscribe. In the parlance of two-sided-market literature, the author singlehomes because he gives a single journal exclusive rights to his article. Readers multihome in the sense that they are not tied to a single journal ex ante but are willing to subscribe to whichever of them secures the article ex post.<sup>29</sup>

Begin the analysis of exogenous market structures with the case of exactly one of each in the market, i.e.,  $T = O = 1$ . The subscription stage is unchanged from the monopoly case. If the traditional journal attracts the article, it monopolizes this vis-a-vis readers; the open-access journal

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<sup>29</sup>Our assumption of a representative article somewhat obscures readers' multihoming behavior. Readers end up subscribing to at most one journal; the consequence of multihoming is that this journal is not selected ex ante. With multiple articles the multihoming behavior would be more apparent.

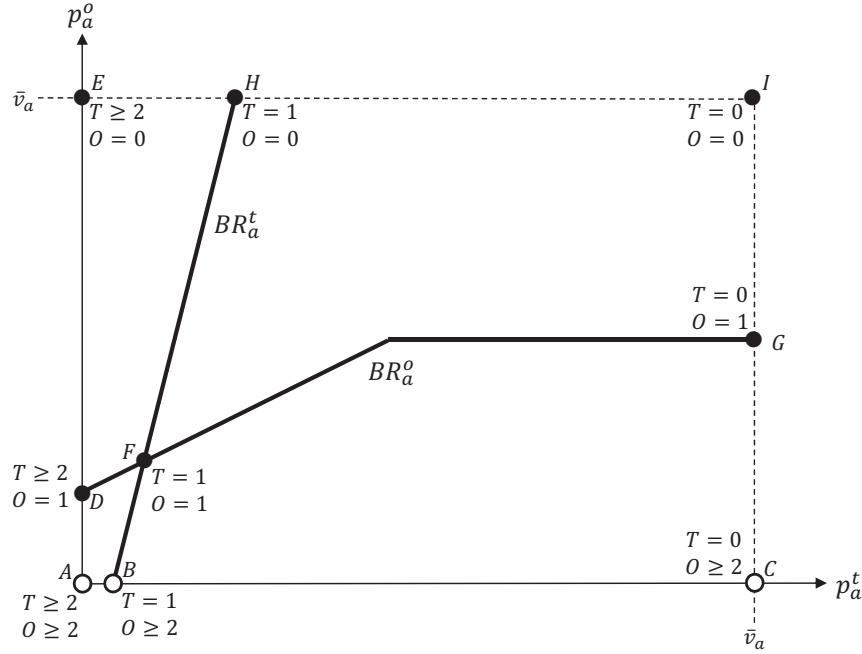


Figure 2  
Best-Response Functions for Competing Traditional and Open-Access Journals

Notes: For reference, equilibria for all other possible exogenous industry configurations also identified, filled dots for outcomes that can be attained as free-entry equilibria and open dots for outcomes that cannot. Coordinates of origin are  $(\max(0, c_a - \pi_r^{mt}), c_a + c_r)$ , reflecting zero-profit constraint on prices; because of this origin shift, price space need not be square.

of course posts the article for free. It remains to determine equilibrium submission fees. The analysis is similar to that for the standard model of vertical quality differentiation (see Shaked and Sutton 1982). The author effectively obtains a higher quality good from the open-access journal in the sense that the entire mass 1 will read the article rather than just the  $q_r^{mt}$  who subscribe to the traditional journal. Thus an author with benefit parameter  $v_a$  obtains gross benefit  $v_a$  from the open-access journal but only  $v_a q_r^{mt}$  from the traditional journal. As is standard in vertical-quality models, the high-quality (i.e., open-access) journal sells at a high price to an interval of the highest values  $v_a$ . The low-quality (i.e., traditional) journal sells at a lower price to authors with lower values of  $v_a$ . With both journals operating in their niches, they are able to charge positive markups.

Figure 2 provides a schematic diagram of competition between exactly one traditional and open-access journal.<sup>30</sup> Journals' best-response functions are drawn as dark curves. Both are the standard solution to respective first-order conditions except that, if  $p_a^t$  is sufficiently high, the open-access journal operates as a monopolist because its higher quality good no longer faces effective competition from the traditional journal for authors. This accounts for the horizontal portion of  $BR_a^o$  at the open-access journals' monopoly price. Equilibrium is given by the intersection of the best-response functions  $BR_a^t$  and  $BR_a^o$  at point  $F$ . With a single open-access journal competes against a single

<sup>30</sup>While the figure serves as a schematic diagram, it is in fact drawn for numerical example with  $c_a = 1/3$ ,  $c_r = 0$ , and  $v_a$  and  $v_r$  uniformly distributed on  $[0, 1]$ . We chose slightly different cost values than in earlier figures because the earlier cost values led some outcomes to collapse that we wanted to distinguish in the schematic diagram. The best-response functions need not be linear for non-uniform distributions.

traditional one, both can earn profit.

Equilibrium for other market structures can also be represented in the figure. Suppose there are  $T \geq 2$  traditional journals in the market and no open-access journals. Using a leading  $c$  in the superscript to denote the case of competition, the equilibrium subscription fee is  $p_r^{ct} = p_r^{mt}$ , i.e., the same as with a monopoly traditional journal. Despite competition for authors in the first stage, whichever journal signs the author up simply behaves as a static monopolist in its dealings with the reader. Competition for authors in the first stage drives the submission fee  $p_a^{ct}$  down to the zero-profit level unless this violates the constraint  $p_a^{ct} \geq 0$ , in which case  $p_a^{ct} = 0$ . One can see from equation (8) that the zero-profit submission fee equals  $c_a - \pi_r^{mt}$ . Putting these facts together,  $p_a^{ct} = \max(0, c_a - \pi_r^{mt})$ . Shifting the origin so this is its horizontal coordinate and setting the submission fee of absent open-access journals to the choke price  $\bar{v}_a$ , equilibrium under this market structure is represented by point  $E$ .

Next suppose there are  $O \geq 2$  open-access journals in the market and no traditional ones. Competition among the journals drives the equilibrium submission fee  $p_a^{co}$  down to the zero-profit level, which by equation (10) is  $p_a^{co} = c_a + c_r$  ( $p_a^{co}$  hits the zero-profit constraint before the zero-price constraint because open-access journals only source of revenue is authors). Shifting the origin so its vertical coordinate is  $c_a + c_r$  and setting the submission fee of absent traditional journals to the choke price  $\bar{v}_a$ , equilibrium under this market structure is represented by point  $C$ .

Next, consider the configuration with  $T = 1$  and  $O \geq 2$ . Competition among the open-access journals forces their submission fee down to the zero-profit level. The traditional journal best-responds to this submission fee. Given that the axes have been scaled so that the origin reflects zero-profit prices, equilibrium in this configuration is given by the intersection of  $BR_a^t$  with the vertical axis, labeled point  $B$ . Analogously, equilibrium with  $T \geq 2$  and  $O = 1$  is given by point  $D$ , the intersection of  $BR_a^o$  with the horizontal axis.

Rounding out the set of market structures, the monopoly case can be represented by setting the submission fee for the operating mode at its monopoly level and the submission fee of the absent mode to the choke price  $\bar{v}_a$ , thus point  $H$  for a monopoly traditional journal and  $G$  for a monopoly open-access journal. Point  $I$  represents the market structure with no journals. In configurations with  $T \geq 2$  and  $O \geq 2$ , the equilibrium submission fee is driven down to the zero-profit level for both types of journal, corresponding to the appropriately shifted origin of the graph, point  $A$ .

Turning from prices to profits, we see that competition does not necessarily destroy all journal profits. A single open-access journal can earn positive profit in competition with one or more traditional journals because the two products are (vertically) differentiated. Multiple competing traditional journals may also be profitable. Why? The inability to commit to subscription fees means that once a journal has assembled a volume of articles, it can earn monopoly rents on the reader side ex post. These rents are not necessarily dissipated in the competition for authors ex ante because submission fees cannot be negative. These two frictions—a floor on submission fees of zero and an inability to commit to subscription fees—lead these perfectly substitutable journals to be imperfect competitors.<sup>31</sup> Competition among open-access journals is more intense. Their commitment prevents them from earning rents on the reader side. Competition for authors squeezes all the rents from that side as well, leading multiple competing open-access journals to earn zero profit. Thus there is a natural asymmetry in the competitiveness of traditional and open-access journals.

That completes our analysis of exogenous market structures. The results can be used as an input into the analysis of a model with endogenous entry, to which we now turn. Suppose a large, ordered

<sup>31</sup>Paradoxically, a necessary condition for competing traditional journals to earn positive profits is that they offer free submission. Our results here echo findings in the literature on consumer switching costs. As noted by Farrell and Klemperer [2007] (footnote 25), an inability to commit to second-stage prices and a nonnegativity constraint on first-stage prices can combine to prevent competition from dissipating the rents earned from locked-in consumers in the second stage.

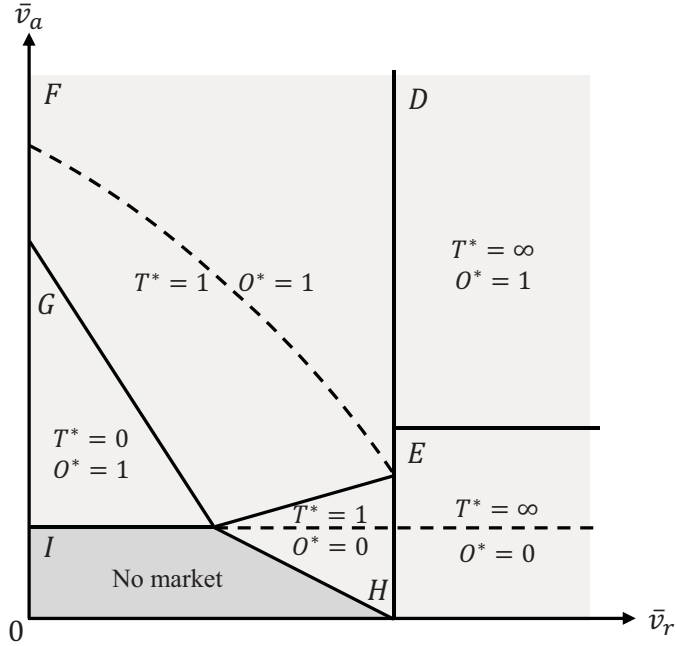


Figure 3  
Free-Entry Outcomes in Numerical Example

Notes: Revisits numerical example from Figure 1, reporting values of  $T$  and  $O$  in free-entry equilibrium in which  $k \rightarrow 0$ . Region labels correspond to filled dots in Figure 2. General conditions characterizing regions provided in Appendix B.

set of potential journals decide in sequence whether to enter or stay out of the market. An entering journal chooses its mode of operating and expends entry cost  $k > 0$ . Both entry and mode decisions are sunk and public.

It is immediate from our analysis of exogenous market structures that equilibrium in the endogenous-entry model cannot involve more than one open-access journal for any  $k > 0$ , no matter how small, because multiple open-access journals earn zero continuation profit after entry. Thus the market structures indicated by the open circles in Figure 2 cannot emerge as endogenous-entry equilibria. It turns out that we can find  $k > 0$  for each of the remaining market structures, indicated by the filled dots, such that each emerges in an endogenous-entry equilibrium. In fact, a single, convenient  $k$  works for all the filled dots: all emerge in equilibrium of the free-entry model, the special, limiting case of the endogenous-entry model in which  $k \rightarrow 0$ . This is documented in Figure 3, which revisits the numerical example from Figure 1 now presenting the outcome under free-entry rather than the monopoly. Variables  $T^*$  and  $O^*$  denote the number of journals of each mode in the free-entry equilibrium. All six of the cases  $D$ – $I$  corresponding to the filled dots show up as nonempty regions in Figure 3.

A core result derived in the baseline, monopoly case was that for a broad range of distributions, open access is never socially excessive (Proposition 3). The next proposition extends this result to the free-entry model. The proof, provided in Appendix B, can be understood using Figure 3 as a schematic diagram representing the general case. The proof shows that reducing the number of open-access journals—which is only possible in regions  $G$ ,  $F$ , and  $D$ , and there amounts to going from one to no open-access journals—does not increase social welfare. Take each region in turn, starting with  $G$ . In that region, the free-entry equilibrium involves a single open-access journal. We show that

the first entrant makes this choice because monopoly open access is more profitable than monopoly traditional access, not because traditional access invites more entry. Given this unambiguous ranking of profits, it is immediate from Proposition 3 that open-access is socially more efficient there as well. Turning to regions  $F$  and  $D$ , equilibrium involves  $T^* > 0$ ; whether  $T^* = 1$  or  $T^* = \infty$  depends only on whether  $\pi_r^{mt} > c_a$ , independent of whether an open-access journal has also entered. Thus eliminating open-access in regions  $F$  and  $D$  removes an open-access competitor holding constant the number of traditional journals. Given that saving  $k$  has negligible social value in the free-entry equilibrium, it is intuitive that such a reduction in competition should not increase welfare; and the proof bears this intuition out formally.

**Proposition 6.** *Suppose that, in addition to being logconcave, densities  $f_a$  and  $f_r$  are nonincreasing. If the free-entry equilibrium involves the operation of an open-access journal, then the socially efficient market structure also involves some open access. On the other hand, cases can be constructed in which the free-entry equilibrium involves the operation of some traditional journals when the socially efficient market structure involves only open access.*

To be clear, the socially efficient market structure in the statement of the proposition does not refer to the first best in which a social planner chooses both market structure and prices. (Traditional and open access may not even be well defined in the first best since the planner would likely choose prices that differ from either of these.) Rather, the socially efficient market structure corresponds to the situation in which a social planner chooses which firms enter but then lets entrants set equilibrium prices.

To summarize, a number of results extend from monopoly to its polar opposite, free entry. (a) Subscription fees remain the same: traditional journals charge  $p_r^{mt}$  and open-access journals zero. (b) Journal profits can still be positive. A lone open-access journal in the market will earn generically positive profits because the threat of tough competition deters other open-access entrants and vertical differentiation with traditional journals allows it to earn a markup. Multiple traditional journals can also earn positive profits because the floor on submission fees keeps them from dissipating all rents, although unlimited entry will dissipate this profit in the free-entry limit. (c) For the same broad class of distributions considered in the monopoly result, open access is never socially excessive but traditional access can be. (d) Results concerning the efficiency of open-access mandates are also robust across market structures, as discussed further in the next subsection.

#### V(v). *Open-Access Mandate*

As discussed in the introduction, a number of funders including the U.S. government, Wellcome Trust, and the Gates Foundation have enacted or considered mandates requiring the results of funded research to be made openly accessible, in effect barring the author from submitting to a traditional journal. Traditional journals are threatened not just by legal mandates but also by the illegal operation of Sci-Hub and other websites offering open access to pirated articles. We will model both open-access mandates and the growth of piracy as a ban on traditional journals. Our model can be used to evaluate the welfare effects of such a ban.

The welfare effects of banning traditional journals can be easily understood referring back to Figures 1 and 3. We will discuss each in turn starting with Figure 1, which we will use to illustrate the effect of banning traditional journals in a monopoly market. The ban has no effect in regions  $A$  and  $C$  because a traditional journal does not operate there in equilibrium in the absence of a ban. The only regions in which the ban changes the outcome binds and so has the potential to affect welfare are  $B$  and  $D$ . Traditional access less efficient than open access in region  $D$ , so banning it raises welfare there. By contrast, traditional access is more efficient than open access in region  $B$ , so banning

traditional access reduces welfare there. The greatest welfare losses are in the southeast corner of region *B*. When author values are this relatively low, banning traditional access, by increasing submission fees, can lead to large distortions.

We next turn to Figure 3 to illustrate the welfare effects of banning traditional journals in a free-entry equilibrium. The ban has no effect in regions *I* and *G* because no traditional journal operates there in equilibrium even absent a ban. The ban harms welfare in the part of regions *H* and *E* below the dashed line, which we added to delineate the region in which no open-access journal enters to replace the banned traditional journals, leaving the market unserved. The mandate also harms welfare in regions *H* and *E* above the dashed line. There, banning traditional journals induces the entry of an open-access journal, so the market does not go unserved. Still, social welfare turns out to be higher with the traditional journals in this region of relatively high reader to author values. In region *F*, the ban results in the removal of the traditional competitor, moving the market from a duopoly to a monopoly open-access journal. One might think removing a competitor would reduce welfare, and this is in fact true in the part of region *F* above the dashed line. Banning traditional journals is even worse for welfare in region *D* because there many competitors are excluded by the ban, not just one. The only place where banning traditional journals increases welfare is in the part of region *F* below the dotted line. It is surprising that excluding a competitor could increase welfare. There reason is that the traditional journal is a fairly ineffective competitor for these parameters, so the welfare loss from reduced competition for authors is dominated by the gain in readers' surplus when authors are forced to submit to an open-access journal.

Figures 1 and 3 paint a dim picture of the welfare effects of a ban on traditional journals. The area of the parameter space for which the ban produces losses is larger than that for which the ban produces gains. The magnitude of the maximum loss is about twice the maximum gain in both figures. These are results from a numerical example, not a general proposition, but they suggest the possibility that banning traditional journals without inquiring into whether the policy is appropriate for the market parameters can be socially quite harmful.

## VI. CONCLUSION

Commentators on the market for academic journals have expressed increasing support for the open-access model. This support raises a puzzle for economists versed in two-sided-market models. With the ability to set any non-negative fee on both the author and reader side, why isn't some interior solution with positive prices on both sides preferable to one with a zero price on the reader side? To be sure, a range of plausible parameters could render a corner solution optimal (as in the part of region *C* to the left of the dashed line in Figure 1). In this paper we identify a potentially broader role for open access. The transition from print to digital journals meant that institutions no longer retain permanent access to content on library shelves but effectively rent access through a journal's portal. A journal may like to promise that it will maintain low subscription fees to attract submissions from authors who value wide readership into the future (with attendant increases in cites and prestige). However, the journal may be unable to commit to a particular sequence of positive subscription fees in the future, leading to a potential hold-up problem, whereby the journal monopolizes the reader side once it attracts submissions rather than expanding readership as the authors would prefer. In this paper, we identify the fundamental role of open access as a crude solution to this hold-up problem, a commitment to zero subscription fees into the future, which can be credible even if some nuanced sequence of positive fees would not be.

The comparison between traditional and open-access journals raises a non-trivial tradeoff, that between unbridled hold-up and a crude solution to it. Our analysis of this tradeoff raised some interesting theoretical possibilities.

- *Viability of Open Access:* Open access can be profitable for a commercial journal. The loss of revenue on the reader side may be more than compensated by solving the hold-up problem on the author side, especially if author values are very high relative to reader values.
- *Journal Competition:* While a single open-access journal can be profitable, competition among them is severe, dissipating their profits, so that only one ever ends up in the market in an endogenous-entry model. Competing traditional journals may enter and remain profitable. Similar to the finding in the literature on consumer switching costs (see Farrell and Klemperer 2007, footnote 25), competition for first-stage consumers (authors in our setting) may not fully dissipate rents earned on second-stage consumers (locked-in consumers in that setting, readers in our setting) when a nonnegativity constraint on first-stage prices binds.
- *Efficiency of Open Access:* For a class of distributions (nonincreasing, logconcave), open access is never socially excessive but traditional access can be. Expanded access generates consumer surplus for readers as a by-product of the increased quality of the product offered to authors, an externality present in this two-sided market absent from standard, one-sided markets.
- *Efficiency of Traditional Access:* While traditional access can be socially excessive for some parameters, for other parameters traditional access can be socially efficient. In the limit as reader values dominate author values, social welfare hinges on providing the high-value readers with articles to read, which a traditional journal does by keeping submission fees low relative to an open-access journal.

Despite the finding summarized in second bullet point that open access tends to be undersupplied, our analysis in the extensions does not provide universal support for an open-access mandate. Such a mandate effectively eliminates the traditional journal as a business model, which as explained in the last bullet point is sometimes efficient. Unless it is clear that market conditions are ripe for a mandate to produce gains (balanced author and reader values), as we demonstrated in a numerical example, the mandate risks generating potentially huge welfare losses. The introduction mentioned the recent court injunction against Sci-Hub, a comprehensive archive of pirated scholarly articles. If injunctions fail to curtail readers' growing acceptance, Sci-Hub could limit journals' ability to charge positive subscription fees, all but destroying the traditional journal as a business model in the same way as a broad mandate. Thus our analysis could be used to predict the effect on welfare from the external imposition of open access, whether the result of legal mandates coming from research funders or Sci-Hub's illegal operation.

The model can also contribute to an understanding of the recent rise of "megajournals," open-access journals with low rejection rates that publish vast numbers of articles. This is the niche in which commercial publishers have undertaken the most open-access activity. Proposition 2 captures the case of vanishing journal quality controls, leading to vanishing reader benefits, in the limiting result  $\alpha \rightarrow 0$ . The proposition guarantees that open access is more profitable than traditional access in this case.

The extension to bundling clarifies why this strategy has been such a powerful force in the market. Institution-specific prices for the whole bundle of a publisher's journal can extract most of the surplus from the reader side while keeping readership high. Bergstrom *et al.* [2014] find that lower-tier universities in some cases pay less per citation for for-profit bundles than they do for nonprofit journals. Reaching most readers this way, authors have little reason not to submit to journals published by large commercial bundlers as long as submission there is cheap (which the bundler has every incentive to ensure). The model predicts powerful incentives for commercial



publishers to bundle and consolidate but, once complete, there are no natural market forces to disrupt bundlers' dominance. The only effect of competition among them would be to reduce submission fees to zero; subscription revenues would be unchanged, essentially reaching the level from first-degree price discrimination.

The extension to hybrid pricing explains the growing popularity of this pricing strategy in the market, as it provides journals with another pricing instrument allowing more surplus to be extracted. We see that the five Elsevier journals in Table I in the data appendix adopted hybrid pricing, as have most Springer and Wiley journals. While the option is pervasively offered, to date, it has only rarely been taken up. For only 3% of the articles published in 2015 in the five Elsevier journals in Table I did the authors pay the \$1,800 premium for the open-access option. The model would predict this outcome in an environment in which hybrid pricing overlays bundling. Authors already reach most of their target audience if they publish in a bundled journal, so few would pay as much as \$1,800 to expand readership further.

APPENDIX A  
DATA APPENDIX

The introduction provided several facts about the journals market for background. This appendix provides tables and figures of results referenced there as well as details behind the data used to construct these exhibits.

*Journal Pricing Facts*

Table I reports journal fees from a panel of the top economics journals by profit status, updating a study by Bergstrom [2001]. To maintain a balanced panel, we use Bergstrom’s [2001] list of top five journals of each profit status ranked by total cites to the journal in 1998. Subscription fees for 1985 and 2001 are drawn from Tables 5 and 6 of Bergstrom [2001]. The 1985 fees are scaled down by Bergstrom’s [2001] inflation factor of 1.59 to express them in nominal terms. Subscription fees for 2016 are taken from Ulrich’s Periodicals Directory ([www.ulrichsweb.com/ulrichsweb](http://www.ulrichsweb.com/ulrichsweb)). The authors hand collected submission fees for 1985 and 2001 from the journals’ front or back matter. The 2016 submission fee and author fees for gold open access were obtained from individual journal websites (all downloads made on March 22, 2016).

*Analysis of DOAJ Data*

Here we provide details behind the trends in number of open-access journals mentioned in the introduction. The analysis is based on data from the Directory of Open Access Journals (DOAJ). In the absence of systematic data on the number of open-access journals in operation—a variable that would net out exits from entries—we focus on cumulative gross entry. Some work is needed to infer this variable from DOAJ data since the current DOAJ registry omits those journals that entered

TABLE I  
FEES FOR TOP ECONOMICS JOURNALS BY PROFIT STATUS

Journal	Subscription fee			Submission fee			Gold open-access publication fee 2016
	1985	2001	2016	1985	2001	2016	
<b>Top five nonprofit journals</b>							
<i>American Economic Review</i>	33	45	105	50	150	200	—
<i>Econometrica</i>	87	241	550	0	0	193	—
<i>Journal of Political Economy</i>	50	175	559	40	50	125	2,500
<i>Quarterly Journal of Economics</i>	48	198	738	0	0	0	2,800
<i>Journal of Finance</i>	40	207	445	20	140	250	—
Mean	52	173	479	22	68	154	2,650
<b>Top five for-profit journals</b>							
<i>Journal of Financial Economics</i>	175	1,429	4,274	150	400	750	1,800
<i>Journal of Economic Theory</i>	410	1,800	4,347	0	0	0	1,800
<i>Journal of Econometrics</i>	463	2,020	4,089	25	50	75	1,800
<i>Journal of Monetary Economics</i>	146	1,078	3,336	75	175	250	1,800
<i>Journal of Public Economics</i>	398	1,546	3,975	0	50	100	1,800
Mean	199	1,575	4,134	50	135	235	1,800

*Notes:* Fees in nominal U.S. dollars. Dash indicates option for author to pay for gold open access not available. Means rounded to the nearest dollar. Subscription fees for print and online access to a volume for a U.S. institutional subscriber. Subscription fee for *American Economic Review* is its share of subscription fee for it and the other American Economic Association journals bundled with it at that time. Submission fees are for non-members. All of the top five for-profit journals published by Elsevier.

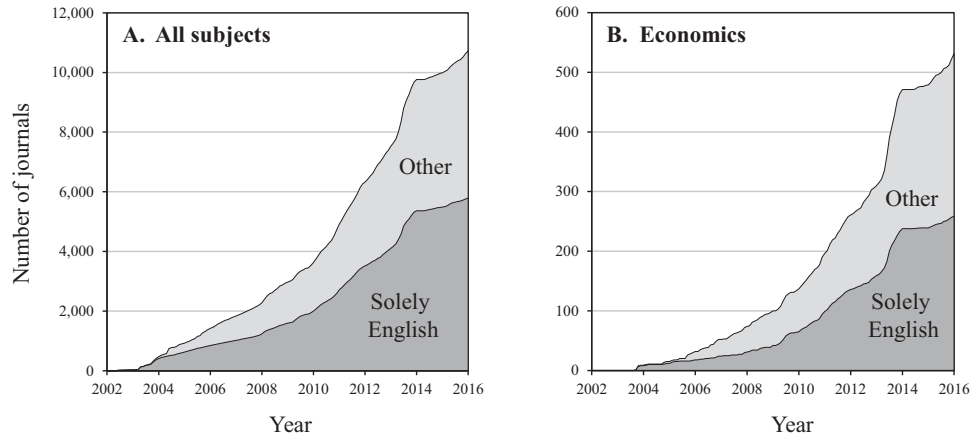


Figure 4  
Open Access Growth in the Journals Market

Notes: Source is series constructed by authors from DOAJ data. Exits are not netted out. Panels have different scales for the number of journals on the vertical axis.

before 2014 but then were delisted as part of DOAJ’s initiative to improve its registration standards. To add the entry of these journals back in, we merge the DOAJ database downloaded on March 22, 2016 with one downloaded on August 1, 2014 before the DOAJ began delisting. The resulting database includes information on title, publisher, subjects, keywords, headquarters country, and date first registered on DOAJ for 10,725 open-access journals. Figure 4 graphs the resulting series for all disciplines (Panel A) and economics (Panel B).

The introduction quotes growth rates for various categories of open-access journal. To formally estimate these growth rates, we run the ordinary least squares regression  $\ln Y_t = \alpha + \beta t + \epsilon_t$ , where  $Y_t$  be the number of journals in a given category,  $\alpha$  and  $\beta$  are coefficients to be estimated, and  $\epsilon_t$  is an error term. Then  $\hat{\beta}$  provides an estimate of the growth rate. To allow for different growth

TABLE II  
REGRESSIONS ESTIMATING GROWTH RATE OF OPEN-ACCESS JOURNALS

	All subjects				Economics			
	All languages		English speaking		All languages		English speaking	
Time trend 2003-16 ( $\beta$ )	0.33*** (0.05)		0.30*** (0.04)		0.34*** (0.02)		0.31*** (0.01)	
Time trend 2003-14 ( $\beta_0$ )		0.38*** (0.06)		0.34*** (0.06)		0.38*** (0.02)	0.34*** (0.01)	
Time trend 2014-16 ( $\beta_1$ )		0.07 (1.07)		0.05 (0.94)		0.11 (0.32)	0.08 (0.10)	
Observations	14	14	14	14	13	13	13	

Notes: Ordinary least squares regressions of natural log of number of journals in a category on a time trend. Constants also included—alone or interacted with indicators for pre- or post-2014—but coefficients not reported. Standard errors reported in parentheses. Significantly different from 0 in a two-tailed test at the \*10% level, \*\*5% level, \*\*\*1% level.

rates before and after 2014, we re-run the regression interacting the constant and time trend with indicators  $1_{\{t < 2014\}}$  and  $1_{\{t \geq 2014\}}$  for the relevant time periods. Table II reports the results.

Broken down by subject, biology and medicine accounted for 43% of open-access journals at the end of 2015, followed the social sciences (26%), humanities (15%), and other sciences and engineering (15%). The United States headquartered the largest share (12%), followed by Brazil (9%), the United Kingdom (6%), with over 120 countries headquartering at least one.

APPENDIX B  
PROOFS OF PROPOSITIONS

This appendix provides proofs of the propositions stated in the text.

*Proof of Proposition 1*

We prove the result by nesting the objective functions of the two modes of journal operation together using the parameter  $\theta$  and then applying Edlin and Shannon's [1998] Strict Monotonicity Theorem 1 to provide the necessary comparative statics result with respect to  $\theta$ .

Nesting the ex-ante expected profit function for a traditional journal, (8), with that for an open-access journal, (10), yields

$$(B1) \quad \Pi^m = M(p_a, \theta) \bar{F}_a \left( \frac{p_a}{D(\theta)} \right),$$

where  $M(p_a, \theta) = p_a - c_a + (1 - \theta)\pi_r^{mt} - \theta c_r$  is unit profit and  $D(\theta) = (1 - \theta)q_r^{mt} + \theta$  is shorthand for the denominator of the argument of author demand. The nesting parameter takes on the values  $\theta = 0$  for a traditional journal and  $\theta = 1$  for an open-access journal. The first-order condition associated with (B1) is

$$(B2) \quad \frac{\partial \Pi^m}{\partial p_a} = \bar{F}_a - \frac{M(p_a, \theta) f_a}{D(\theta)},$$

suppressing the argument of  $\bar{F}_a$ , shown in (B1), and well as the same argument of  $f_a$ . Differentiating this condition again,

$$(B3) \quad \frac{\partial^2 \Pi^m}{\partial p_a \partial \theta} = \frac{(1 - q_r^{mt}) f_a}{D(\theta)} \left[ \frac{\pi_r^{mt} + c_r}{1 - q_r^{mt}} + \frac{p_a + M(p_a, \theta)}{D(\theta)} + \frac{M(p_a, \theta) p_a}{D(\theta)^2} \left( \frac{f'_a}{f_a} \right) \right].$$

We seek to determine the sign of (B3). Given the assumed logconcavity of  $f_a$ , by Corollary 2 of Bagnoli and Bergstrom [2005], the failure rate  $r_a = f_a / \bar{F}_a$  is nondecreasing. Thus

$$(B4) \quad \frac{f'_a}{f_a} \geq \frac{-f_a}{\bar{F}_a} = \frac{-D(\theta)}{M(p_a, \theta)}.$$

The first step in (B4) follows from  $r_a \geq 0$ . The second step follows from setting the first-order condition (B2) equal to 0 and rearranging. Substituting (B4) into (B3) and collecting terms yields

$$(B5) \quad \frac{\partial^2 \Pi^m}{\partial p_a \partial \theta} \geq \frac{(1 - q_r^{mt}) f_a}{D(\theta)} \left[ \frac{\pi_r^{mt} + c_r}{1 - q_r^{mt}} + \frac{M(p_a, \theta)}{D(\theta)} \right].$$

The right-hand side is positive because all the factors are. To see this, the fact that the monopoly journal earns positive profit implies that unit profit  $M(p_a, \theta)$  is positive. It is obvious that  $D(\theta)$  and the other factors are also positive.

We have thus shown that (B1) has strictly increasing marginal returns. We argued in Section IV(iii) that  $p_a^{mo}$  is an interior solution. Strict Monotonicity Theorem 1 then implies  $p_a^{mo} > p_a^{mt}$ .

The promised counterexample having non-logconcave  $f_a$  in which  $p_a^{mo} < p_a^{mt}$  is provided in online Appendix D, available on this journal's editorial web site.  $\square$

*Proof of Proposition 2*

Before proceeding with the proof, some notation is in order. Focus for now on the original consumer values,  $v_i$ , rather than the rescaled values,  $\omega_i$ , for  $i \in \{a, r\}$ . Let  $p_i^*$  be the solution to the problem of maximizing revenue treating side  $i$  as a stand-alone market with the original values:

$$(B6) \quad p_i^* = \operatorname{argmax}_{p_i \geq 0} [p_i \bar{F}_i(p_i)].$$

Let  $\pi_i^* = p_i^* \bar{F}_i(p_i^*)$  denote maximized revenue. The assumption that  $\bar{v}_i > 0$  implies  $\pi_i^* > 0$ . The assumption that  $E(v_i) < \infty$  implies that  $\pi_i^* < \infty$  since

$$(B7) \quad \pi_i^* = p_i^* \bar{F}_i(p_i^*) = \int_{p_i^*}^{\bar{v}_i} p_i^* f_i(v_i) dv_i \leq \int_{p_i^*}^{\bar{v}_i} v_i f_i(v_i) dv_i \leq \int_0^{\bar{v}_i} v_i f_i(v_i) dv_i = E(v_i).$$

Recording these facts for reference,

$$(B8) \quad \pi_i^* \in (0, \infty).$$

We will introduce some further notation regarding rescaled consumer values,  $\omega_i$ , defined by the proposition as  $\omega_a = \alpha v_a$  on the author side and  $\omega_r = v_r/\alpha$  on the reader side. Let  $\phi_i$  denote the density function,  $\Phi_i$  the distribution function,  $\bar{\Phi}_i$  the survivor function, and  $[0, \bar{\omega}_i]$  the support for  $\omega_i$ .

We begin by proving the claim about profits in the first statement of the proposition. Profit for a traditional journal is

$$(B9) \quad \Pi^{mt} = \max_{p_a \geq 0} [(p_a - c_a + \pi_r^{mt}) \bar{\Phi}_a(p_a/q_r^{mt})]$$

$$(B10) \quad \geq (0 - c_a + \pi_r^{mt}) \bar{\Phi}_a(0/q_r^{mt})$$

$$(B11) \quad = \pi_r^{mt} - c_a$$

$$(B12) \quad = \max_{p_r \geq 0} [(p_r - c_r) \bar{\Phi}_r(p_r)] - c_a$$

$$(B13) \quad \geq \max_{p_r \geq 0} [p_r \bar{\Phi}_r(p_r)] - (c_a + c_r)$$

$$(B14) \quad = \frac{\pi_r^*}{\alpha} - (c_a + c_r).$$

Equation (B9) follows from (8). Equation (B10) holds because  $p_a = 0$  is not necessarily a maximizer of the right-hand side of (B9). Equation (B11) follows from evaluation, (B12) follows from the definition of  $\pi_r^{mt}$ , and (B13) follows from  $\bar{\Phi}_r(p_r) \leq 1$ . To see (B14), first note

$$(B15) \quad \bar{\Phi}_r(p_r) = \Pr(\omega_r \geq p_r) = \Pr(v_r/\alpha \geq p_r) = \Pr(v_r \geq \alpha p_r) = \bar{F}_r(\alpha p_r).$$

Hence

$$(B16) \quad \max_{p_r \geq 0} [p_r \bar{\Phi}_r(p_r)] = \max_{p_r \geq 0} [p_r \bar{F}_r(\alpha p_r)] = \frac{1}{\alpha} \max_{z_r \geq 0} [z_r \bar{F}_r(z_r)] = \frac{\pi_r^*}{\alpha},$$

where the first step holds by (B15), the second step by change of variables  $z_r = \alpha p_r$ , and the last step and then by (B6). Taking limits in (B9)–(B14), we have

$$(B17) \quad \lim_{\alpha \rightarrow 0} (\alpha \Pi^{mt}) \geq \pi_r^* > 0,$$

where the last inequality follows from (B8).

Profit for an open-access journal is

$$(B18) \quad \Pi^{mo} = \max_{p_a \geq 0} [(p_a - c_a - c_r) \bar{\Phi}_a(p_a)]$$

$$(B19) \quad = \max_{p_a \geq 0} [(p_a - c_a - c_r) \bar{F}_a(p_a/\alpha)]$$

$$(B20) \quad = \alpha \max_{z_a \geq 0} \left[ \left( z_a - \frac{c_a + c_r}{\alpha} \right) \bar{F}_a(z_a) \right]$$

$$(B21) \quad \leq \alpha \max_{z_a \geq 0} [z_a \bar{F}_a(z_a)]$$

$$(B22) \quad = \alpha \pi_a^*$$

$$(B23)$$

Equation (B9) follows from (10), (B19) follows from a derivation analogous to (B15), (B20) follows from the change of variables  $p_a/\alpha = z_a$ , (B21) follows from  $c_r \geq 0$ , and (B22) follows from (B6). Taking limits in (B18)–(B22), we have

$$(B24) \quad \lim_{\alpha \rightarrow 0} (\alpha \Pi^{mo}) \leq \lim_{\alpha \rightarrow 0} (\alpha^2 \pi_a^*) = 0.$$

where the last inequality follows from  $\pi_a^* < \infty$  by (B8). Together, (B17) and (B24) imply that  $\Pi^{mt} > \Pi^{mo}$  for sufficiently small  $\alpha > 0$ , establishing the claim about profits in the first statement of the proposition.

We next prove the claim about social welfare in the first statement of the proposition. Social welfare for a traditional journal satisfies

$$(B25) \quad \lim_{\alpha \rightarrow 0} (\alpha SW^{mt}) \geq \lim_{\alpha \rightarrow 0} (\alpha \Pi^{mt}) \geq \pi_r^*,$$

where the first inequality follows from  $SW^{mt} \geq \Pi^{mt}$  and the second follows from (B17).

Social welfare for an open-access journal is

$$(B26) \quad SW^{mo} = \int_{p_a^{mo}}^{\bar{\omega}_a} \int_0^{\bar{\omega}_r} (\omega_a + \omega_r) \phi_a(\omega_a) \phi_r(\omega_r) d\omega_a d\omega_r - (c_a + c_r) q_a^{mo}$$

$$(B27) \quad = \int_{p_a^{mo}}^{\bar{\omega}_a} \omega_a \phi_a(\omega_a) d\omega_a + E(\omega_r) \bar{\Phi}_a(p_a^{mo}) - (c_a + c_r) q_a^{mo}$$

$$(B28) \quad < \alpha E(v_a) + \frac{E(v_r)}{\alpha} \bar{F}_a(p_a^{mo}/\alpha).$$

Equation (B26) follows from substituting  $p_r^{mo} = 0$  and  $q_r^{mo} = 1$  into (5). Equation (B27) follows from evaluation. Some work is required to see (B28). The first term of (B27) can be bounded as

$$(B29) \quad \int_{p_a^{mo}}^{\bar{\omega}_a} \omega_a \phi_a(\omega_a) d\omega_a = \int_{p_a^{mo}}^{\bar{\omega}_a} \omega_a \left[ \frac{f_a(\omega_a/\alpha)}{\alpha} \right] d\omega_a$$

$$(B30) \quad = \alpha \int_{p_a^{mo}/\alpha}^{\bar{v}_a} v_a f_a(v_a) dv_a$$

$$(B31) \quad \leq \alpha \int_0^{\bar{v}_a} v_a f_a(v_a) dv_a$$

$$(B32) \quad = \alpha E(v_a),$$

where (B29) follows from the formula for the density of a transformed random variable, (B30) by the change of variables  $\omega_a = \alpha v_a$ , (B31) by reducing the lower limit of integration with a positive integrand, and (B32) by definition. In the second term of (B27), we can substitute  $E(\omega_r) = E(v_r/\alpha) = E(v_r)/\alpha$ . We can also substitute, using an argument similar to (B15),  $\bar{\Phi}_a(p_a^{mo}) = \bar{F}_a(p_a^{mo}/\alpha)$ . We simply drop the last negative term of (B27).

Multiplying (B26)–(B28) through by  $\alpha$  and taking limits,

$$(B33) \quad \lim_{\alpha \rightarrow 0} (\alpha SW^{mo}) \leq E(v_a) \lim_{\alpha \rightarrow 0} \alpha^2 + E(v_r) \lim_{\alpha \rightarrow 0} \bar{F}_a(p_a^{mo}/\alpha).$$

The expected values in both terms are finite by assumption. Thus expression (B33) equals 0 if each limit on the right-hand side equals 0. Obviously the first does. We will show the second does, too. Consider the equivalent expression for  $\Pi^{mo}$  provided in (B20). For all  $z_a \in [0, \bar{v}_a)$ , there exists  $\alpha > 0$  sufficiently small that the maximand in (B20) is negative because  $c_a + c_r \geq c_a > 0$  by assumption. For all  $z_a \geq \bar{v}_a$  on the other hand,  $\bar{F}_a(z_a) = 0$ , implying the maximand in (B20) equals 0 for all  $\alpha > 0$ . Letting  $z_a^{mo}$  denote the maximizer of (B20), we have thus shown  $\lim_{\alpha \rightarrow 0} z_a^{mo} \geq \bar{v}_a$ . By the change of variables behind the definition of  $z_a$ ,  $z_a^{mo} = p_a^{mo}/\alpha$ . Hence  $\lim_{\alpha \rightarrow 0} (p_a^{mo}/\alpha) \geq \bar{v}_a$ , implying  $\lim_{\alpha \rightarrow 0} \bar{F}_a(p_a^{mo}/\alpha) = 0$ .

Putting our results together,  $\lim_{\alpha \rightarrow 0} (\alpha SW^{mt}) \geq \pi_r^* > 0 \geq \lim_{\alpha \rightarrow 0} (\alpha SW^{mo})$ , where the first inequality follows from (B25), the second from (B8), and the third from our results that the limits in (B33) equal 0. Therefore,  $SW^{mt} > SW^{mo}$  for sufficiently small  $\alpha > 0$ . This completes the proof of the first statement of the proposition. The second statement, the mirror image of the first, is proved analogously.  $\square$

### *Proof of Proposition 3*

Return to the original consumer values  $v_i$  for  $i \in \{a, r\}$  with no rescaling. Assume densities  $f_i$ , in addition to being logconcave, are nonincreasing. Rather than working with submission fees  $p_a$ , the proof is streamlined if we express them instead in per-reader terms  $z_a = p_a/q_r$  because this allows an ‘‘apples-to-apples’’ comparison of prices across modes of operation. We emphasize that the journal sets lump-sum submission fees, not per-reader fees, in our game; the game would be quite different if it chose the latter. One can see that we are solving the correct game by noting that  $q_r$  is taken to be exogenous, not depending on  $z_a$ , but fixed at  $q_r^{mt}$  for a traditional journal and 1 for an open-access journal.

As mentioned in the sketch, the proof involves a worst-case analysis, which the following optimal-control problem, labeled MIN1, embodies:

$$(B34) \quad \min_{f_a, f_r} (SW^{mo} - SW^{mt})$$

$$(B35) \quad \text{subject to } \Pi^{mo} \geq \Pi^{mt}$$

$$(B36) \quad f_a'(v_a) \leq 0$$

$$(B37) \quad f_r'(v_r) \leq 0$$

$$(B38) \quad f_a \text{ logconcave}$$

$$(B39) \quad f_r \text{ logconcave}$$

$$(B40) \quad \bar{F}_a(0) \leq 1$$

$$(B41) \quad \bar{F}_r(0) \leq 1.$$

The inequalities in (B40) and (B41) are equalities if the densities are Riemann-integrable on their



supports. Treating them inequalities slightly relaxes the problem, allowing the distributions to have mass points at 0. We will show that the value of this relaxed problem MIN1 is nonnegative.

The objective function can be rewritten, after considerable manipulation,

$$(B42) \quad \begin{aligned} SW^{mo} - SW^{mt} = & \int_{z_a^{mo}}^{\bar{v}_a} (v_a - c_a - c_r) f_r(v_r) dv_r - \int_{z_a^{mt}}^{\bar{v}_a} [(v_a - c_r) q_r^{mt} - c_a] f_a(v_a) dv_a \\ & + \bar{F}_a(z_a^{mo}) \underbrace{\int_0^{p_r^{mt}} v_r f_r(v_r) dv_r}_{I_1} - [\bar{F}_a(z_a^{mt}) - \bar{F}_a(z_a^{mo})] \underbrace{\int_{p_r^{mt}}^{v_r} v_r f_r(v_r) dv_r}_{I_2}. \end{aligned}$$

Now if  $z_a^{mo} \leq z_a^{mt}$ , it is obvious that (B42) is nonnegative, and we are done. So assume throughout the remainder of the proof that

$$(B43) \quad z_a^{mt} > z_a^{mo}.$$

As an input into the solution of the larger problem, we will first solve several smaller subproblems. Except for the integrals labeled  $I_1$  and  $I_2$ , all terms and factors in the objective (B42) as well as both sides of the constraint (B35) are invariant to changes in  $f_r$  that hold  $p_r^{mt}$  and  $q_r^{mt}$  constant. Furthermore, fixing  $p_r^{mt}$  and  $q_r^{mt}$ , integrals  $I_1$  and  $I_2$  can be optimized independently.

Since the factor in front of  $I_1$  is positive, a necessary condition for a solution to MIN1 is that  $f_r$  minimizes  $I_1$  for given  $p_r^{mt}$  and  $q_r^{mt}$  subject to constraints (B37), (B39), and (B41). We will generate a relaxed version of this problem by omitting logconcavity constraint (B39), which turns out not to bind, as will be verified later. Furthermore, we will replace (B41) with an equivalent condition for it, derived next. Since  $p_a^{mt}$  maximizes  $\pi_r(p_r)$ , it satisfies first-order condition  $0 = \pi'_r(p_r^{mt}) = \bar{F}_r(p_r^{mt}) - (p_r^{mt} - c_r) f_r(p_r^{mt})$ , or upon substituting  $q_r^{mt} = \bar{F}_r(p_r^{mt})$  and rearranging,

$$(B44) \quad f_r(p_r^{mt}) = \frac{q_r^{mt}}{p_r^{mt} - c_r}.$$

But then

$$(B45) \quad 1 - q_r^{mt} \geq \int_0^{p_r^{mt}} f_r(v_r) dv_r \geq \int_0^{p_r^{mt}} f_r(p_r^{mt}) dv_r = \frac{p_r^{mt} q_r^{mt}}{p_r^{mt} - c_r}.$$

The first step follows from noting  $\bar{F}_r(0) = \int_0^{p_r^{mt}} f_r(v_r) dv_r + q_r^{mt}$ , applying (B41), and rearranging. The second step follows from (B37) and the last step from (B44). Thus we will replace (B41) with equivalent condition

$$(B46) \quad 1 - q_r^{mt} \geq \frac{p_r^{mt} q_r^{mt}}{p_r^{mt} - c_r}.$$

The problem of choosing  $f_r$  to minimize  $I_1$  subject to (B37) and (B44) can be translated into the following standard optimal-control problem, labeled MIN2:

$$(B47) \quad \min \int_0^T tx_i dt$$

$$(B48) \quad \text{subject to } \dot{x}_1 = u$$

$$(B49) \quad -u \geq 0$$

$$(B50) \quad x_1(T) = \frac{q_r^{mt}}{p_r^{mt} - c_r},$$

where  $t = v_r$  is the index variable,  $T = p_r^{mt}$  is the given terminal value,  $x_1 = f_r$  is the state variable, and  $u$  is the control variable. Intuitively, if MIN2 were unconstrained, the minimum would be obtained by removing all the mass from  $x_1(t)$  for  $t \leq T$ , driving  $I_1$  down to 0. The best that can be done in the constrained problem is to drive  $x_1(t)$  down to the right-hand side of (B50) for all  $t \in (0, T]$ . Otherwise, either (B49) or (B50) would be violated. Thus the solution to MIN2 is the uniform distribution.

We will derive this intuitive result formally using standard optimal-control techniques. The Hamiltonian and Lagrangian associated with MIN2 are

$$(B51) \quad \mathcal{H} = tx_1 + \lambda_1 u + \lambda_2 x_1$$

$$(B52) \quad \mathcal{L} = \mathcal{H} - \mu u,$$

the latter introduced to accommodate the inequality constraint (B49) on the control. ‘‘Textbook’’ necessary conditions for an optimum are

$$(B53) \quad 0 = \frac{\partial \mathcal{L}}{\partial u} = \lambda_1 - \mu$$

$$(B54) \quad \dot{\lambda}_1 = -\frac{\partial \mathcal{L}}{\partial x_1} = t + \lambda_2$$

$$(B55) \quad \dot{\lambda}_2 = -\frac{\partial \mathcal{L}}{\partial x_2} = 0$$

$$(B56) \quad \mu(-u) = 0$$

$$(B57) \quad \mu \geq 0.$$

Equation (B55) implies  $\lambda_2$  is a constant. Thus (B54) implies  $\dot{\lambda}_1 = 1$ , implying  $\lambda_1$  is strictly concave in  $t$  and thus strictly quasiconcave. Now  $\lambda_1 = \mu \geq 0$  by (B53) and (B57). Thus, for all  $t \in (0, T)$ ,  $\lambda_1(t) > \min[\lambda_1(0), \lambda_1(T)] \geq 0$ , where the first inequality follows from strict quasiconcavity and the second because  $\lambda_1(t) \geq 0$  for all  $t \in [0, T]$  as just shown. Hence, for all  $t \in (0, T)$ ,  $\mu(t) = \lambda_1(t) > 0$ , implying  $u = 0$  by (B56), implying  $\dot{x}_1 = 0$  by (B48). This shows  $x_t(t)$  is the uniform density satisfying (B50); i.e.,

$$(B58) \quad x_1(t) = \frac{q_r^{mt}}{p_r^{mt} - c_r}.$$

The uniform distribution is logconcave, so omitted constraint (B39) is satisfied. If (B46) is not satisfied with equality by (B58), an atom of probability of mass  $1 - m_r$  can be added to  $x_1(0)$  so (B46) does hold with equality without increasing the objective in MIN2.

Returning to the objective function (B42) in the larger problem, the factor in front of of integral  $I_2$  is negative by (B43). Hence a necessary condition for a solution to MIN1 is that  $f_r$  maximize  $I_2$  for given values  $p_r^{mt}$  and  $q_r^{mt}$  subject to constraints (B37), (B39), and (B44), the last equivalent to (B41), as shown. This subproblem, which we will label MAX1, can be set up and solved as an optimal-control problem similar to MIN2. The solution is again the uniform distribution. Deriving this solution turns out to be harder with MAX1 than MIN2 because it is the logconcavity constraint that binds rather than the simpler nonincreasingness constraint. For brevity, we relegate the details of the set up and solution of MAX1 to online Appendix D.

Solving the two subproblems that were inputs into MIN1 has shown that  $f_r$  is the uniform distribution on the whole interval  $[0, \bar{v}_r]$ . We can use this concrete functional form to make some substitutions in (B42) to derive an equivalent objective function. As our solution of MIN2 introduced the possibility of an atom of probability of mass  $1 - m_r$  on zero-value readers. It turns out that this generalization will not affect the subsequent qualitative analysis as it will just add a scale factor that will not change the slope of the relevant curves. For completeness, we will accommodate the generalization here, writing  $f_r(v_r) = m_r/v_r$ . Then  $\bar{F}_r(p_r) = m_r(1 - p_r/\bar{v}_r)$ . Maximizing  $\pi_r(p_r)$  yields  $p_r^{mt} = (\bar{v}_r + c_r)/2$ . Substituting,

$$(B59) \quad q_r^{mt} = \frac{m_r}{2\bar{v}_r}(\bar{v}_r - c_r)$$

$$(B60) \quad \pi_r^{mt} = \frac{m_r}{4\bar{v}_r}(\bar{v}_r - c_r)^2.$$

Further detailed calculations yield the following expressions for the integrals in (B42):

$$(B61) \quad I_1 = \frac{m_r}{8\bar{v}_r}(\bar{v}_r + c_r)^2(\bar{v}_r - c_r)$$

$$(B62) \quad I_2 = \frac{m_r}{8\bar{v}_r}(3\bar{v}_r + c_r)(\bar{v}_r - c_r).$$

Substituting these expressions into (B42) and rearranging,

$$(B63) \quad SW^{mo} - SW^{mt} = \underbrace{\int_{z_a^{mo}}^{\bar{v}_a} \ell_1(v_a) f_a(v_a) dv_a}_{I_3} - \underbrace{\int_{z_a^{mt}}^{z_a^{mo}} \ell_2(v_a) f_a(v_a) dv_a}_{I_4},$$

where

$$(B64) \quad \ell_1(v_a) = (1 - q_r^{mt})(v_a - c_r) + I_1$$

$$(B65) \quad \ell_2(v_a) = q_r^{mt}(v_a - c_r) - c_a + I_2$$

are increasing, affine function of  $v_a$ .

Similar to our earlier approach, we can break the larger problem of minimizing (B63) into the subproblems of choosing  $f_a$  to minimize  $I_3$  on  $[z_a^{mo}, \bar{v}_a]$  and to maximize  $I_4$  on  $[z_a^{mt}, z_a^{mo}]$ . The details of the set up of these subproblems as optimal-control problems and their solutions are relegated to online Appendix D. The solution is the uniform distribution on  $[0, \bar{v}_a]$ . Putting all of our results together, the worst case is generated by a uniform distribution of author values on  $[0, \bar{v}_a]$  and a uniform distribution of reader values on  $[0, \bar{v}_r]$ . Allowing for a possible atom of probability at  $v_r = 0$  of mass  $1 - m_r$ , and considering the costs  $c_a$  and  $c_r$ , this gives five parameters that can be used to minimize the algebraic expression for  $SW^{mo} - SW^{mt}$  that can be derived knowing the distributions are uniform. Numerical methods can be used to calculate the minimized value, which is 0. Hence it is never the case that  $SW^{mo} < SW^{mt}$  when  $\Pi^{mo} \geq \Pi^{mt}$  and under the assumed conditions on  $f_a$  and  $f_r$ .  $\square$

#### *Proof of Proposition 4*

Figure 1 provides the case needed to provide the second statement of the proposition. To prove the first statement, suppose  $p_r^{mc} > 0$ . Then  $p_r^{mc} \neq p_r^{mo}$ , implying  $\Pi^{mc} \neq \Pi^{mo}$ , implying  $\Pi^{mo} < \Pi^{mc} \leq \Pi^{mf}$ . The first inequality follows from  $\Pi^{mc} \neq \Pi^{mo}$  and  $\Pi^{mc} = \max(\Pi^{mt}, \Pi^{mo}) \geq \Pi^{mo}$  and

the second inequality from the fact that full is at least as profitable as crude commitment. Now, if  $p_r^{mf} = 0$ ,  $\Pi^{mf} = \Pi^{mo}$  because  $p_a^{mo}$  is the maximizer in equation (10). Hence  $p_r^{mf} > 0$ .  $\square$

*Proof of Proposition 5*

To prove the first statement of the proposition, suppose the equilibrium fees under crude commitment are uniquely positive:  $p_a^{mc}, p_r^{mc} > 0$ . Since the journal prefers to operate than not,  $\Pi^{mc} > 0$ . Since  $p_a^{mc} \neq 0 = p_r^{mo}$ , open access is dominated in equilibrium:  $\Pi^{mc} > \Pi^{mo}$ . Thus we have  $\Pi^{mt} = \Pi^{mc} > 0$ ,  $p_a^{mt} = p_a^{mc}$ , and  $p_r^{mt} = p_r^{mc}$ .

We will first show  $p_r^{mf} < p_r^{mt}$ . We know  $p_r^{mt} > 0$  because  $\bar{v}_r > 0$  by assumption. If  $p_r^{mf} = 0$ , we are done showing  $p_r^{mf} < p_r^{mt}$ . We will proceed with the comparison of subscription fees by assuming  $p_r^{mf} > 0$ .

Full-commitment fees  $p_a^{mf}$  and  $p_r^{mf}$  must satisfy the first-order condition found by differentiating (1) with respect to  $p_r$ . This first-order condition can be rearranged as

$$(B66) \quad \pi'_r(p_r^{mf})q_a^{mf} = \Pi^{mf} \frac{f_a(p_a^{mf}/q_r^{mf})f_r(p_r^{mf})p_a^{mf}}{(q_a^{mf})^3}.$$

The right-hand side is positive since  $\Pi^{mf} \geq \Pi^{mc} > 0$ . Thus the left-hand side must be positive as well, implying  $\pi'_r(p_r^{mf}) > 0$ . Bagnoli and Bergstrom [2005] (p. 463) prove that the logconcavity of  $f_r$  implies  $\pi_r(p_r)$  is quasiconcave. Quasiconcavity, together with the facts that  $\pi'_r(p_r^{mf}) > 0$  and  $\pi'_r(p_r^{mt}) = 0$ , imply  $p_r^{mf} < p_r^{mt} = p_r^{mc}$ .

This completes the comparison of subscription fees. Turn to the comparison of submission fees. The proof that  $p_a^{mf} > p_a^{mc}$ , relying on the logconcavity of  $f_a$ , is similar to the proof of Proposition 1 and is omitted.

Suppose  $p_a^{mf} = 0$ . Substituting into (1), the journal's full-commitment profit is  $\max_{p_r \geq 0} [\pi_r(p_r) - c_a]$  because its quantity is  $Q_a(0, p_r) = \bar{F}_a(0) = 1$ . Obviously, this commitment profit is maximized by  $p_r^{mf} = p_r^{mt}$ . The traditional journal can achieve the full-commitment profit  $\Pi^{mf}$  by setting  $p_a^{mt} = p_a^{mf} = 0$ , which must be an optimum for the traditional journal since  $\Pi^{mf}$  is an upper bound on  $\Pi^{mt}$ .  $\square$

*General Conditions for Regions in Figure 3*

This proof derives general conditions for the regions in Figure 3. First suppose  $\pi_r^{mt} > c_a$ . Even if traditional entry forces the submission fee down to where the nonnegativity constraint binds, as equation (8) shows, they will earn a positive margin, which will not be reduced with further entry because of the nonnegativity constraint on prices. For any finite  $T$ , traditional journals will sell some positive quantity even if an open-access journal is in the market because this open-access journal must charge a positive submission fee to earn any profit, so authors whose values are in a neighborhood above 0 will buy from one of the traditional journals. For any finite  $T$ , traditional entry is profitable, so  $T^* = \infty$  in the free-entry equilibrium.

If  $\pi_r^{mt} > c_a$ , therefore, a potential open-access entrant would have to compete against free submission to a traditional journal. If the highest-value author does not submit to the open-access journal no author will. This author obtains net surplus  $q_r^{mt}\bar{v}_a$  if he submits to a traditional journal (with free submission) and  $\bar{v}_a - p_a^o$  if he submits to the open-access journal charging  $p_a^o$ . Hence, the open-access journal will serve a positive measure of customers only if  $p_a^o < (1 - q_r^{mt})$ . By equation (10), the open-access journal earns a positive margin only if  $p_a^o > c_a + c_r$ . Putting these facts together,

$O^* = 1$  (corresponding to region  $D$  in the figure) if  $(1 - q_r^{mt})\bar{v}_a > c_a + c_r$ , and  $O^* = 0$  (corresponding to region  $E$ ) if the reverse weak inequality holds.

Suppose for the remainder of the proof that  $\pi_r^{mt} \leq c_a$ . Then multiple traditional journals would not enter because competition among them would force the submission fee down to the zero-profit constraint (hit before the nonnegativity constraint because of the assumed condition), so they would be unable to cover their entry cost  $k$ , however small. At most one traditional journal enters. If  $\bar{v}_a \leq c_a + c_r$ , then an open-access journal could not break even by serving even the highest-value author. So  $O^* = 0$ . A monopoly traditional journal can make positive profit by serving the highest-value author (and a neighborhood below) if  $q_r^{mt}\bar{v}_a - c_a + \pi_r^{mt} > 0$ . Hence  $T^* = 1$  (corresponding to region  $H$ ) if that inequality holds. Otherwise, if the reverse weak inequality holds,  $T = 0$  (corresponding to the no-market region,  $I$ ).

Suppose for the remainder of the proof that  $\bar{v}_a > c_a + c_r$ . Then an open-access journal may enter. Let  $\Pi^{Ft}$  and  $\Pi^{Fo}$  be the profits of the traditional and open-access journal, respectively, in the duopoly structure with one of each journal mode indicated by point  $F$  in Figure 2. If  $\min(\Pi^{Ft}, \Pi^{Fo}) > 0$ , the  $T^* = O^* = 1$  (corresponding to region  $F$  of Figure 3). If  $\Pi^{Ft} \leq 0 < \Pi^{Fo}$ , then  $T^* = 0$  and  $O^* = 1$  (corresponding to region  $G$ ). If  $\Pi^{Fo} \leq 0 < \Pi^{Ft}$ , then  $T^* = 1$  and  $O^* = 0$  (corresponding to region  $H$ ). Suppose instead  $\max(\Pi^{Ft}, \Pi^{Fo}) \leq 0$ . Then if  $\Pi^{mt} \geq \Pi^{mo}$ ,  $T^* = 1$  and  $O^* = 0$  (corresponding to region  $H$ ), while if  $\Pi^{mo} \geq \Pi^{mt}$ ,  $T^* = 0$  and  $O^* = 1$  (corresponding to region  $G$ ).  $\square$

#### *Proof of Proposition 6*

We will compare social welfare in the free-entry equilibrium, with the configuration of journals  $(T^*, O^*)$ , to that with  $(T', O')$  journals, where  $O'$  represents an exogenous reduction in the number of open-access journals, i.e.,  $O' < O^*$ , and  $T'$  represents the best response of potential entrants to the reduction in open access journals. We argued in the text that  $O^* \leq 1$ . Hence, for  $O' < O^*$ , we must have  $O' = 0$  and  $O^* = 1$ . A reduction in open-access journals makes traditional entry weakly more attractive, so since  $T'$  is a best response to  $O'$ ,  $T' \geq T^*$ . This leaves us six cases to analyze, to which we will assign labels corresponding to the regions in Figure 3. We can start with a free-entry equilibrium in region  $G$  with  $(T^*, O^*) = (0, 1)$  and move to  $(T', O') = (0, 0)$  (case G.1) or to  $(T', O') = (1, 0)$  (case G.2) or to  $(T', O') = (\infty, 0)$  (case G.3). Or we can start with a free-entry equilibrium in region  $F$  with  $(T^*, O^*) = (1, 1)$  and move to  $(T', O') = (1, 0)$  (case F.1) or to  $(T', O') = (\infty, 0)$  (case F.2). Or we can start with a free-entry equilibrium in region  $D$  with  $(T^*, O^*) = (\infty, 1)$  and move to  $(T', O') = (\infty, 0)$  (case D.1). We will analyze each case in turn showing that none produces a social welfare increase.

In case G.1, social welfare is nonnegative in the free-entry equilibrium but zero in the new outcome with no firms, so does not increase.

Since case G.2 involves  $(T^*, O^*) = (0, 1)$ , by the previous proof, the following conditions must hold: either  $\Pi^{mo} \geq \max(0, \Pi^{mt})$  and  $\max(\Pi^{Ft}, \Pi^{Fo}) \leq 0$  (subcase G.2a) or  $\Pi^{mo} > 0$  and  $\Pi^{Ft} \leq 0 < \Pi^{Fo}$  (subcase G.2b). In subcase G.2a, the fact that  $\Pi^{mo} \geq \max(0, \Pi^{mt})$  implies  $SW^{mo} \geq SW^{mt}$  by Proposition 3. It can also be shown that the conditions behind subcase G.2b entail  $\Pi^{mo} \geq \Pi^{mt}$ . The argument is sufficiently intricate that we relegate it to the online appendix (Appendix D).

Case G.3 is infeasible. By the previous proof,  $T' = \infty$  if and only if  $\pi_r^{mt} > c_a$ . But then  $T^* = \infty$  rather than  $T^* = 0$  as specified in the subcase. Case F.2 is infeasible for the same reason.

In case F.1, let  $SW^F$  be equilibrium social welfare in duopoly structure  $F$ , and note  $SW^{mt}$  is equilibrium social welfare in the outcome after removing the open-access journal  $(T', O') = (1, 0)$ . Let  $z_a^{Ft}$  be the lowest author type served by the traditional journal in the duopoly structure  $F$ , let  $z_a^{Fo}$  be the lowest type served by the open-access journal in that structure, and let  $z_a^{mt}$  be the lowest type served by a monopoly traditional journal. After some rearranging, we have  $SW^F - SW^{mt} = I_5 + I_6$ ,

where

$$(B67) \quad I_5 = \int_{z_a^{Ft}}^{z_a^{mt}} \left[ \int_{p_r^{mt}}^{\bar{v}_r} (v_a + v_r - c_r) f_r(v_r) dv_r - c_a \right] f_a(v_a) dv_a$$

$$(B68) \quad I_6 = \int_{z_a^{Fo}}^{\bar{v}_a} \left[ \int_{p_r^{mt}}^{\bar{v}_r} (v_a + v_r - c_r) f_r(v_r) dv_r - c_a \right] f_a(v_a) dv_a.$$

We will show both integrals are positive. We have

$$(B69) \quad I_5 > \int_{z_a^{Ft}}^{z_a^{mt}} \left[ \int_{p_r^{mt}}^{\bar{v}_r} (v_a + p_r^{mt} - c_r) f_r(v_r) dv_r - c_a \right] f_a(v_a) dv_a = \int_{z_a^{Ft}}^{z_a^{mt}} (q_r^{mt} v_a - c_a + \pi_r^{mt}) f_a(v_a) dv_a,$$

where the first step follows from  $v_r > p_r^{mt}$  for  $v_r$  between the integration limits, and the second step follows from straightforward evaluation. For all  $v_a > z_a^{Ft}$ ,  $q_r^{mt} v_a > q_r^{mt} z_a^{Ft} \geq p_a^{Ft} > c_a - \pi_r^{mt}$ , where the weak inequality holds because the marginal author type cannot obtain negative net surplus and the last inequality holds because  $\Pi^{Ft} > 0$  in case F.1 as shown in the previous proof, implying the margin on authors  $p_a^{Ft} - c_a + \pi_r^{mt}$  must be positive. Thus the last integrand in (B69) is positive. Turning to the other integral,

$$(B70) \quad I_6 > \int_{z_a^{Fo}}^{\bar{v}_a} \left[ \int_{p_r^{mt}}^{\bar{v}_r} (v_a - c_r) f_r(v_r) dv_r - c_a \right] f_a(v_a) dv_a = \int_{z_a^{Fo}}^{\bar{v}_a} [(v_a - c_r)(1 - q_r^{mt}) - c_a] f_a(v_a) dv_a,$$

where the first step follows from  $v_r > 0$ , and the second follows from evaluation. We will show that the last integrand in (B70) is positive. Marginal type  $z_a^{Fo}$  must weakly prefer submitting to the open-access over the traditional journal in structure  $F$ :  $z_a^{Fo} - p_a^{Fo} \geq q_r^{mt} z_a^{Ft} - p_a^{Ft}$ . Rearranging and recognizing the nonnegativity constraint on  $p_a^{Ft}$ , we have

$$(B71) \quad (1 - q_r^{mt}) z_a^{Fo} \geq p_a^{Fo}.$$

Thus, for all  $v_a \geq z_a^{Fo}$ , we have  $(1 - q_r^{mt}) v_a \geq (1 - q_r^{mt}) z_a^{Fo} \geq p_a^{Fo} > c_a + c_r \geq c_a + (1 - q_r^{mt}) c_r$ , where the second inequality follows from (B71) and the third from (D53). Rearranging the preceding series of inequalities shows that the last integrand in (B70) is positive.

Analysis of the remaining case, D.1, is similar and thus relegated to online Appendix D.  $\square$

APPENDIX C  
ANALYSIS OF HYBRID JOURNAL

This appendix provides a formal analysis of the model of a monopoly hybrid journal introduced in Section V(iii).

An author submitting to the hybrid journal can choose one of the two access options. If he opts for traditional access, the continuation equilibrium from that point on is identical to that in Section IV(ii). In particular, an expected number of readers  $q_r^{mt}$  access the article at a subscription fee of  $p_a^{mt}$  generating profit from the readers of  $\pi_r^{mt}$ . If the author opted for open access, the continuation equilibrium is identical to that in Section IV(iii). In particular, the representative reader accesses the article and (by definition) no revenue is earned on him.

Folding the game back to the second stage, the author now has three options: not submit, submit and opt for traditional access, or submit and opt for open access. Author behavior is similar to that described in Section V(iv) where authors had to choose between a competing traditional and open-access journal. The only difference here is that a single journal is offering a menu of the two options. Section D4 provides a detailed analysis of the author's equilibrium strategy in this continuation game. There it is proved that the set of author types is partitioned into three subintervals, as illustrated in Figure 5. The lowest values choose not to submit, intermediate values choose to submit under traditional access, and the highest values submit and pay the premium for open access. The general analysis is complicated by the fact that one or two of these subintervals can be empty depending on the journal's menu of prices  $(p_a, x_a)$ , leading to a proliferation of cases. To reduce this proliferation, in this section we will focus on the interesting case of journal that is a non-trivially hybrid, that is, a journal whose equilibrium price menu leads to a positive measure of authors selecting traditional access and a positive measure selecting open access. Proposition 8 provides sufficient conditions for this case to arise in equilibrium.

Consider the author's strategy as a function of his or her value  $v_a$  shown in Figure 5. The boundary between the first two subintervals is given by the author type who is indifferent between earning 0 by not submitting and earning  $q_a^{mt}v_a - p_a$  by submitting under traditional access. Rearranging, this condition becomes  $v_a = p_a/q_a^{mt}$ . The boundary between the last two subintervals is given by the type who is indifferent between earning  $q_a^{mt}v_a - p_a$  by submitting under traditional access and earning  $v_a - p_a - x_a$  by submitting under open access. Rearranging, this condition becomes  $v_a = x_a/(1 - q_a^{mt})$ . If  $p_a = 0$ , then the first subinterval is empty. All authors then submit an article, in the non-trivial case some choosing traditional and others open access.

Folding the game back to the first stage, the hybrid journal chooses the price menu  $(p_a, x_a)$  to

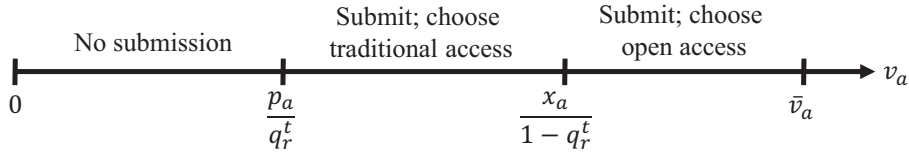


Figure 5  
Author's Equilibrium Continuation Strategy Facing a Hybrid Journal

*Notes:* If all author prices are positive, author values are partitioned into three subintervals. The lowest values do not submit articles, intermediate values submit under traditional access, and the highest values pay the premium for open access. If basic submission is free ( $p_a = 0$ ), then the first subinterval is empty; hence all types submit an article.

maximize profit:

$$(C1) \quad (p_a - c_a + \pi_r^{mt}) [\bar{F}_a(p_a/q_r^{mt}) - \bar{F}_a(x_a/(1-q_r^{mt}))] + (p_a + x_a - c_a - c_r) \bar{F}_a(x_a/(1-q_r^{mt})),$$

or, rearranging,

$$(C2) \quad (p_a - c_a + \pi_r^{mt}) \bar{F}_a(p_a/q_r^{mt}) + (x_a - c_a - \pi_r^{mt}) \bar{F}_a(x_a/(1-q_r^{mt})).$$

The first term is identical to the profit for a monopoly traditional journal from (8). The second term is independent of  $p_a$ , involving only  $x_a$ . Thus, it is immediate that we have a dichotomy result, whereby a hybrid journal ignores the open-access option when setting the basic submission fee  $p_a$ , setting this fee exactly as would a traditional journal.

The first-order condition for the open-access premium can be rearranged into the following Lerner index formula

$$(C3) \quad L_a^{hx} = \frac{x_a^h - (1 - q_r^{mt})c_r}{x_a^h} = \frac{1}{|\eta_a^{hx}|} + \frac{p_r^{mt} q_r^{mt}}{x_a^h}.$$

where  $\eta_a^{hx} = \frac{\partial}{\partial x_a} \bar{F}_a(x_a^h/(1-q_r^{mt})) x_a^h/q_a^h$  is the elasticity of author demand for open access evaluated at the equilibrium premium and  $q_a^h = \bar{F}_a(p_a^h/q_r^{mt})$  is the number of submissions. There are several points to notice about (C3). The relevant marginal cost that is being subtracted in the numerator is the cost per reader  $c_r$  of serving the  $1 - q_r^{mt}$  readers attracted by open access. The Lerner index is positive and is higher than the standard inverse elasticity rule for a monopolist by the term  $p_r^{mt} q_r^{mt}/x_a^h$ , reflecting the revenue lost from subscribers who would have paid for access to the article. The hybrid journal is reluctant to lose this revenue, and marks up the open-access premium accordingly.

Characterizing the remaining elements of the hybrid journal's equilibrium strategy is straightforward. As already noted, readers will be charged the monopoly price  $p_r^{mt}$  if the representative author selected restricted access, and  $q_r^{mt}$  will subscribe to it. If the representative author selected open access, then all readers will access the article for free. The following proposition summarizes the preceding analysis.

**Proposition 7.** *Assume that in equilibrium the monopoly hybrid journal serves a positive measure of authors choosing traditional access and a positive measure choosing open access (online Appendix E, available on this journal's editorial web site, provides sufficient conditions). Then its basic submission fee and number of submissions are the same as for a monopoly traditional journal: i.e.,  $p_a^h = p_a^{mt}$  and  $q_a^h = q_a^{mt}$ . If the submitting author selects restricted access, readers pay the same subscription fee and the same number of readers subscribe as with a monopoly traditional journal, i.e.,  $p_r^h = p_r^{mt}$  and  $q_r^h = q_r^{mt}$ . If the submitting author selects open access, readers pay no subscription fee, and all readers access the article. Averaged across possible author choices, the expected subscription fee is  $(q_a^{mt} - q_a^h) p_r^{mt}$  and the expected number of readers who access the article by  $q_a^{mt} q_r^{mt} + q_a^h (1 - q_r^{mt})$ .*

The proposition is consistent with some stylized empirical facts concerning economics journals. So far, the large commercial publishers, which recently moved to hybrid from the traditional pricing model, have not made marked changes to their basic submission fees. In Table I, for example, annual growth in the mean submission fee shrank from 6.4% over 1985–2001 to 3.8% over 2001–16; the ratio of mean for-profit to nonprofit submission fee fell from 2.0 in 2001 to 1.5 in 2016. Mean subscription fees for the for-profit journals in Table I have risen more slowly recently than historically—6.6% annually from 2001–2016, down from 13.8% annually from 1985–2001—and the ratio of the median for-profit to nonprofit subscription fees has fallen—from 9.1 in 2001 to 8.6



in 2016. While in principle this moderation could be explained by the discount for freely available content embodied in the formula for subscription fees stated in the proposition, i.e.,  $(q_a^{mt} - q_a^h)p_r^{mt}$ , in practice only 3% of the articles published in 2015 by the for-profit journals in Table I chose open access, which should have a small effect on submission fees according to the formula.  $\square$

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