Online Appendices for “Open Access as a Crude Solution to a Hold-up Problem in the Two-Sided Market for Academic Journals”

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Description: This document contains three appendices not included in the published paper for space considerations. The appendix included in the published paper, Appendix A, contains proofs of propositions. Appendix B included here provides further details omitted from those proofs. Appendix C included here provides details behind the analysis in Section 3.2 of trends in open access using data from the Directory of Open Access Journals (DOAJ). Appendix D included here provides a full analysis of a hybrid journal, complementing the sketch provided in the paper.

Online Appendix B: Further Proof of Selected Propositions

Some propositions require a technical proof, but the arguments are similar enough to those in Appendix A (supplied with the paper) that for space considerations we have omitted them from the paper and included them in this online appendix, not for publication. For some propositions the entire proof is included here and for others just the proof of selected statements.

Completing Proof of Proposition 4: Here we provide the counterexample, promised in the text following the proposition, having non-log-concave f^a in which $p^a_{mo} < p^a_{mt}$. The counterexample involves discrete distributions of author and reader values, but it is easy to construct continuous distributions approaching these discrete distributions in the limit. Suppose v^a takes on two values, 2 or 2.9, in equal measure. Suppose v^r also takes on two values, 0 for 30% of readers and a small, positive number, say 0.0001, for the remainder. Suppose $c^a = 1$ and $c^r = 0$. It follows that $\pi^r_{mt} \approx 0$ and $q^r_{mt} = 0.7$. Both types of journal have two possible pricing strategies: serving all authors with a low submission fee or serving just high-value ones with a high submission fee. One can show that a traditional journal earns approximately 0.4 from charging 1.4 and serving all authors and approximately 0.515 from charging 2.03 and serving just the high-value ones. Thus $p^a_{mt} = 2.03$. An open-access journal earns 1 from charging 2 and serving all authors and 0.95 from charging 2.9 and serving just the high-value ones. Thus $p^a_{mo} = 2 < 2.03 = p^a_{mt}$. □

Completing Proof of Proposition 5: The first statement of the proposition was proved in Appendix A. To prove the second statement, let random variable $\omega^r = \theta^r v^r$ denote the scaled reader value, with distribution function Φ^r, density ϕ^r, and support $[0, \bar{\omega}^r]$. Total profit from a monopoly open-access journal π_{mo} is a constant, independent of θ^r. Total profit from a monopoly traditional journal is

$$\pi_{mt} = \max_{p^a \geq 0} \left\{ (p^a - c^a + \pi^r_{mt}) \left[1 - F^a \left(\frac{p^a}{q^r_{mt}} \right) \right] \right\} \tag{B1}$$

$$
\begin{aligned}
&\geq \pi^r_{mt} - c^a && \text{(B2)}\\
&= \max_{p^r \geq 0}\{(p^r - c^r)[1 - \Phi^r(p^r)]\} - c^a && \text{(B3)}\\
&= \max_{p^r \geq 0}\left\{(p^r - c^r)\left[1 - F^r\left(\frac{p^r}{\theta^r}\right)\right]\right\} - c^a && \text{(B4)}\\
&\geq \theta^r \max_{z^r \geq 0}\{z^r[1 - F^r(z^r)]\} - c^a - c^r. && \text{(B5)}
\end{aligned}
$$

Step (B2) holds because $p^a = 0$ is not necessarily a maximizer of (B1), (B3) holds by definition, (B4) holds by the formula for the distribution of a transformed random variable, and (B5) holds by change of variable $z^r = p^r/\theta^r$ and by subtracting off a full c^r. Now

$$
\max_{z^r \geq 0}\{z^r[1 - F^r(z^r)]\} > 0. \tag{B6}
$$

Hence (B5) implies $\lim_{\theta^r \to \infty} \pi_{mt} = \infty > \pi_{mo}$. □

Proof of Proposition 6: To prove the first statement of the proposition, let random variable $\omega^r = \theta^r v^r$ denote the scaled reader value, with distribution function, density, and support as given in the proof of Proposition 5. Total profit for a monopoly open-access journal is

$$
\pi_{mo} = \max_{p^a \geq 0}\{(p^a - c^a - c^r)[1 - F^a(p^a)]\}. \tag{B7}
$$

Note π_{mt} is independent of θ^r and is positive when $\bar{v}^a > c^a + c^r$ because the interval $[c^a + c^r, \bar{v}^a]$ has positive measure.

To bound total profit for a monopoly traditional journal, first examine equilibrium in the reader stage. Continuation profit from readers can be bounded as follows:

$$
\begin{aligned}
\pi^r_{mt} &= \max_{p^r \geq 0}\{(p^r - c^r)[1 - \Phi^r(p^r)]\} && \text{(B8)}\\
&\leq \max_{p^r \geq 0}\{p^r[1 - \Phi^r(p^r)]\} && \text{(B9)}\\
&= \max_{p^r \geq 0}\left\{p^r\left[1 - F^r\left(\frac{p^r}{\theta^r}\right)\right]\right\} && \text{(B10)}\\
&= \theta^r \max_{z^r \geq 0}\{z^r[1 - F^r(z^r)]\}, && \text{(B11)}
\end{aligned}
$$

following steps similar to those used in the proof of Proposition 5. But $E(v^r)$ is finite, and

$$
z^r[1 - F^r(z^r)] \leq E(v^a),
$$

implying $z^r[1 - F^r(z^r)]$ is finite. Equation (B11) then implies $\lim_{\theta^r \to 0} \pi^r_{mt} = 0$. Reader quantity can also be bounded. We have $q^r_{mt} \leq 1 - \Phi^r c^r = 1 - F^r(c^r/\theta^r)$. Hence $0 \leq \lim_{\theta^r \to 0} q^r_{mt} \leq \lim_{\theta^r \to 0}[1 - F^r(c^r/\theta^r)] = 0$, implying $\lim_{\theta^r \to 0} q^r_{mt} = 0$.

Applying these insights to total profit for a monopoly traditional journal, for any given author price p^a, the limit of author quantity is $\lim_{\theta^r \to 0}[1 - F^a(p^a/q^r_{mt})] = 0$. Thus $\lim_{\theta^r \to 0} \pi_{mt} = 0 < \pi_{mo}$ under the condition $\bar{v}^a > c^a + c^r$.

To prove the second statement of the proposition, let random variable $\omega^a = \theta^a v^a$ denote the scaled author value, with distribution function, density, and support as given in the proof of Proposition 5. We have $0 \leq q^a_{mo} \leq 1 - \Phi^a c^a = 1 - F^a(c^a/\theta^a)$. But $c^a > 0$ implies $\lim_{\theta^a \to 0}[1 - F^a(c^a/\theta^a)] = 0$, in turn implying $\lim_{\theta^a \to 0} q^a_{mo} = 0$. But then $\lim_{\theta^a \to 0} \pi_{mo} = 0$ because the open-access journal earns non-positive profit from readers in all cases and makes no sales to authors, and so earns no profit from them, in the limit.

On the other hand, total profit for a monopoly traditional journal is

$$\begin{aligned} \pi_{mt} &= \max_{p^a \geq 0} \{(p^a - c^a + \pi^r_{mt})[1 - \Phi^a(p^a)]\} && \text{(B12)} \\ &\geq \pi^r_{mt} - c^a && \text{(B13)} \\ &> 0, && \text{(B14)} \end{aligned}$$

where (B13) holds upon substituting $p^a = 0$, which is not necessarily a maximizer of (B12), and (B14) holds under the maintained condition $\pi^r_{mt} > c^a$. Under that condition, $\pi_{mt} > 0 = \pi_{mo}$. □

Completing Proof of Proposition 7: The first statement of the proposition was proved in Appendix A. The second statement includes two results, one comparing profits, one comparing social welfare. That a traditional journal is more profitable than an open-access one in the limit $\theta^a \to 0$ was directly stated in Proposition 6. It is left to prove that a traditional journal generates higher social welfare than an open-access one. The proof of Proposition 6 showed that an open-access journal serves no authors in the limit $\theta^a \to 0$ and thus generates vanishingly little social welfare. Social welfare from a traditional journal exceeds profit π_{mt}, shown to be positive in the proof of Proposition 6 when $c^a < \pi^r_{mt}$. □

Completing the Proof of Proposition 12: We will use arguments similar to the proof of Proposition 4 to show that $p^a_{mf} > p^a_{mt}$. Suppose throughout the proof that f^a is log-concave. Nesting ex ante expected profits for a traditional journal, (5), with that for a journal with full commitment, (11), yields

$$\begin{aligned} \pi_m &= \left[p^a - c^a + \theta(\pi^r_{mf} - \pi^r_{mt}) + \pi^r_{mt}\right] \left[1 - F^a\left(\frac{p^a}{\theta(q^r_{mf} - q^r_{mt}) + q^r_{mt}}\right)\right] && \text{(B15)} \\ &= A(p^a, \theta)\left[1 - F^a\left(\frac{p^a}{B(\theta)}\right)\right], && \text{(B16)} \end{aligned}$$

where $\theta = 0$ for a traditional journal and $\theta = 1$ for a journal with full commitment. The only endogenous variable in (B15) is p^a; the rest including π^r_{mf}, π^r_{mt}, q^r_{mf}, and q^r_{mt} are independent of p^a. For brevity, we substituted $A(p^a, \theta) \equiv p^a - c^a + \theta(\pi^r_{mf} - \pi^r_{mt}) + \pi^r_{mt}$ and $B(\theta) \equiv \theta(q^r_{mf} - q^r_{mt}) + q^r_{mt}$ for those recurring expressions in (B16).

Differentiating (B16) with respect to p^a,

$$\frac{\partial \pi_m}{\partial p^a} = 1 - F^a - \frac{A(p^a, \theta) f^a}{B(\theta)}. \qquad \text{(B17)}$$

For brevity, the argument of F^a, shown in (B15), has been suppressed, as has the argument of f^a. Differentiating this condition again and rearranging,

$$\frac{\partial^2 \pi_m}{\partial p^a \partial \theta} = \frac{f^a}{B(\theta)^2}\left\{(\pi^r_{mt} - \pi^r_{mf})B(\theta) + (q^r_{mf} - q^r_{mt})A(p^a, \theta) + p^a(q^r_{mf} - q^r_{mt})\left[1 + \left(\frac{f^{a\prime}}{f^a}\right)\frac{A(p^a, \theta)}{B(\theta)}\right]\right\}. \qquad \text{(B18)}$$

Using similar steps used in (A9), which rely on the log-concavity of f^a, we have here, likewise, that $f^{a\prime}/f^a \geq -B(\theta)/A(p^a, \theta)$. Substituting into (B18),

$$\frac{\partial^2 \pi_m}{\partial p^a \partial \theta} \geq \frac{f^a}{B(\theta)^2}\left[(\pi^r_{mt} - \pi^r_{mf})B(\theta) + (q^r_{mf} - q^r_{mt})A(p^a, \theta)\right] \qquad \text{(B19)}$$

The right-hand side of (B19) is positive because all factors are. To see this, note $p^r_{mf} < p^r_{mt}$ implies $\pi^r_{mf} < \pi^r_{mt}$ because p^r_{mt} is a maximizer of stand-alone reader profit, which being quasiconcave has a unique maximizer. Further, $Q^{r\prime} < 0$ and $p^r_{mf} < p^r_{mt}$ implies $q^r_{mf} > q^r_{mt}$. Having established $\partial^2\pi_m/\partial p^a \partial\theta > 0$, the remainder of the proof closely follows that of Proposition 4. □

Online Appendix C: Analysis of DOAJ Data

This online appendix, not for publication, provides details on the analysis in Section 3.2 of trends in open access using data from the Directory of Open Access Journals (DOAJ). The main exhibit in that section, Figure 1, focuses on cumulative gross entry. A reasonable alternative measure of the extent of open access, the number of operating journals, would require netting out journal exits, requiring comprehensive data on exits, which is not available. The current DOAJ registry does omit those journals that entered before 2014 but then were de-listed for various reasons including inactivity. To pick up the entry of these journals, we merge the DOAJ database downloaded on March 22, 2016 with one downloaded on August 1, 2014 before the DOAJ began de-listing. The resulting database includes information on title, publisher, subjects, keywords, headquarters country, and date first registered on DOAJ for 10,725 open-access journals.

Section 3.2 quotes some growth rates of various categories of open-access journal. To formally estimate these growth rates, we run an ordinary least squares regression of the form

$$\ln Y_t = \alpha + \beta t + \epsilon_t, \tag{C1}$$

where Y_t be the number of journals in a given category, α and β are coefficients to be estimated, and ϵ_t is an error term. Then $\hat{\beta}$ provides an estimate of the growth rate. To allow for different growth rates in the pre- and post-2014 periods, we run the regression

$$\ln Y_t = I(t < 2014)(\alpha_0 + \beta_0 t) + I(t \geq 2014)(\alpha_1 + \beta_1 t) + \epsilon_t, \tag{C2}$$

Table 2: Regressions estimating average growth in number of open-access journals

	All subjects				Economics			
	All languages		English speaking		All languages		English speaking	
Time trend 2003-16 (β)	0.331*** (0.050)		0.299*** (0.044)		0.336*** (0.022)		0.305*** (0.013)	
Time trend 2003-14 (β_0)		0.384*** (0.063)		0.343*** (0.056)		0.377*** (0.021)		0.336*** (0.007)
Time trend 2014-16 (β_1)		0.072 (1.069)		0.053 (0.941)		0.107 (0.316)		0.081 (0.104)
Observations	14	14	14	14	13	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 but coefficients $\hat{\alpha}$, $\hat{\alpha}_0$, and $\hat{\alpha}_1$ not reported. Standard errors reported in parentheses. Significantly different from 0 in a two-tailed test at the *10% level, **5% level, ***1% level.

where $I(t < 2014)$ and $I(t >= 2014)$ are indicator variables for the relevant time periods. Table 2 provides the results for all subjects and economics alone, and by all languages and English alone.

Online Appendix D: Detailed Analysis of Hybrid Journals

This online appendix provides a full analysis of the hybrid-pricing strategy touched on in the Section-8.4 extension.

D1. Model

Repeating the setup of the model from the text, 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. Journals' first move is to set author prices. The hybrid journal sets a menu of two prices. We will 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 $p^a + x^a$.

D2. Monopoly Hybrid Journal

Start by considering a monopoly hybrid journal. If the author opted for traditional access, the continuation equilibrium in the third and fourth stages is identical to that in Section 6.1. 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 π^r_{mt}. If the author opted for open access, the continuation equilibrium is identical to that in Section 6.2. 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 7.3 where authors had to choose between competing journals, one offering traditional access, another offering open access. 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 D1. 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 15 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 D1. 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.

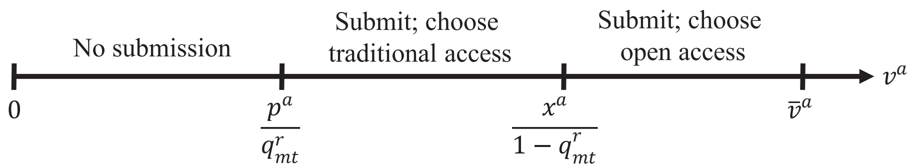


Figure D1: Author's equilibrium continuation strategy when facing a hybrid journal. If all author prices are positive, author values are partitioned into three subintervals. The lowest values do not submit articles, intermediate values submit under traditional access, and the highest values pay the premium for open access. If basic submission is free ($p^a = 0$), then the first subinterval is empty; hence all types submit an article.

Folding the game back to the first stage, the hybrid journal chooses the price menu (p^a, x^a) to maximize profit:

$$(p^a - c^a + \pi^r_{mt})\left[F^a\left(\frac{x^a}{1-q^r_{mt}}\right) - F^a\left(\frac{p^a}{q^r_{mt}}\right)\right] + (p^a + x^a - c^a - c^r)\left[1 - F^a\left(\frac{x^a}{1-q^r_{mt}}\right)\right], \tag{D1}$$

or, rearranging,

$$(p^a - c^a + \pi^r_{mt})Q^a(p^a, q^r_{mt}) + (x^a - c^a - \pi^r_{mt})Q^a(x^a, 1 - q^r_{mt}). \tag{D2}$$

The first term is identical to the profit for a monopoly traditional journal from (5). 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

$$L^a_{mhx} \equiv \frac{x^a_{mh} - (1 - q^r_{mt})c^r}{x^a_{mh}} = \frac{1}{|\eta^a_{mhx}|} + \frac{p^r_{mt} q^r_{mt}}{x^a_{mh}}. \tag{D3}$$

where

$$\eta^a_{mhx} \equiv \frac{Q^a_1(x^a_{mh}, 1 - q^r_{mt})x^a_{mh}}{Q^a(x^a_{mh}, 1 - q^r_{mt})} \tag{D4}$$

is the elasticity of author demand for open access evaluated at the equilibrium premium. There are several points to notice about (D3). 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 $p^r_{mt} q^r_{mt} / x^a_{mh}$, 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. Averaging across possible author choices, the expected subscription fee is

$$[Q^a(p^a_{mt}, q^r_{mt}) - Q^a(x^a_{mh}, 1 - q^r_{mt})]p^r_{mt} \tag{D5}$$

and number of readers with access to the article is

$$Q^a(p^a_{mt}, q^r_{mt})q^r_{mt} + Q^a(x^a_{mh}, 1 - q^r_{mt})(1 - q^r_{mt}). \tag{D6}$$

Summarizing the preceding analysis, we have the following proposition.

Proposition 14. *Assume that, in equilibrium, the monopoly hybrid journal serves a positive measure of* *authors choosing traditional access and a positive measure choosing open access (the next proposition will provide sufficient conditions). Then its basic submission fee* p^a_{mh} *and number of submissions* q^a_{mh} *are the same as for a monopoly traditional journal stated in Proposition 2, i.e.,* $p^a_{mh} = p^a_{mt}$ *and* $q^a_{mh} = q^a_{mt}$*. 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.,* $p^r_{mh} = p^r_{mt}$ *and* $q^r_{mh} = q^r_{mt}$*. If the submitting author selects open access, readers pay no subscription fee, and all readers access the article. Averaged across different author choices, the expected subscription fee is given by equation* (D5) *and expected number of readers who access the article by* (D6)*.*

Proposition 14 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 1, 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 non-profit submission fee fell from 2.0 in 2001 to 1.5 in 2016. Mean subscription fees for the for-profit journals in Table 1 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 non-profit 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 embodied in (D5) for freely available content, in practice only 3% of the articles published in 2015 by the for-profit journals in Table 1 chose open access, which should have a fairly negligible effect on submission fees according to the formula.

D3. Competition with a Hybrid Journal

Next we turn to the case in which a hybrid journal competes against other journals of different kinds, whether traditional, open-access, or themselves also hybrid. For concreteness, start by considering a market with one hybrid and one traditional journal. It would be in the hybrid journal's interest to cede traditional access to its competitor and commit to offer only open access. By so doing, it would end up at the point of intersection of the best response curves in Figure 4 labeled $|T| = 1, |O| = 1$. The outcome would be equivalent to competition between one traditional and one open-access journal. Facing only indirect competition, the traditional journal would maintain a reasonably high submission fee.

By assumption, however, the hybrid journal cannot commit not to offer a menu of options to the author. Standard Bertrand undercutting arguments can be used to show that both journals will compete the submission fee for traditional access down to $p^a_{ct} = \max(0, c^a - \pi^r_{mt})$. The actual equilibrium would be given by the point labeled $|T| \geq 2, |O| = 1$ in Figure 4. Competition with the hybrid journal for traditional access leads the traditional journal to cut its submission fee to the lowest feasible level.

We see that competition between a hybrid and traditional journal leads to the same outcome as if the two segments of the hybrid journal's operation act as independent competitors in the market. This insight generalizes. Adding a hybrid journal to a market with other journals has the same effect on competition as adding two individual journals, one traditional and one open-access. Thus, competition between a hybrid and one or more traditional journals yields the same outcome as the point labeled $|T| \geq 2, |O| = 1$ in Figure 4. Competition between a hybrid and one or more open-access journals yields the same outcome as the point labeled $|T| = 1, |O| \geq 2$. Competition among two or more hybrid journals (as well as any number of other types of journal) yields the same outcome as the point labeled $|T| \geq 2, |O| \geq 2$.

The hybrid option is generally profitable in the monopoly setting—see Proposition 15 for sufficient conditions, which are quite broad—because it provides the journal with another instrument for surplus extraction. Unfortunately for the journal, this extra instrument intensifies competition when other journals in the market, reducing profits when all adopt hybrid pricing, similar to defecting in the Prisoners Dilemma. Unlike in the monopoly case, where the introduction of the open-access premium had no effect on the rest

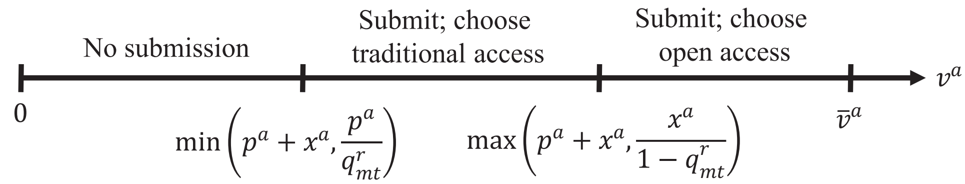


Figure D2: General characterization of author's equilibrium continuation strategy when facing a hybrid journal. Author value per reader partitioned into three subintervals. Author does not submit article for lowest values, submits under traditional access for intermediate values, and pays premium for open access for highest values. Depending on the prices (p^a, x^a) set by the hybrid journal, up to two subintervals may be empty.

of the price structure, under competition, the introduction of hybrid pricing can have an effect similar to a change in the market structure itself. As discussed in the monopoly section, we did not see such marked changes in the market for economics journals. One possible explanation is that the journals market is closer to monopoly than competition. Another is that hybrid pricing interacts with another pricing strategy, bundling, analyzed in the text in Section 8.2. As we will discuss, bundling can render hybrid pricing irrelevant: bundles can reach more readers with institution-specific prices, reducing the benefit of open-access option to the point that few authors pay for it. This may explain the small percentage (3%) of articles that chose open access among those published in 2015 by the for-profit journals in Table 1, an explanation that would hold regardless of the structure of the journal market (monopoly or competition).

D4. Sufficient Conditions for Non-Trivial Hybrid Journal

As discussed in Section D2, analyses of the reader-pricing stage and the subscription stage are identical to those already given. Thus the game can be folded back to the author submission stage. The author has three options: not submitting, providing him with surplus 0; submitting under traditional access, providing him with surplus $v^a q^r_{mt} - p^a$; and submitting under open access, providing him with surplus $v^a - p^a - x^a$. The author chooses the option providing him with the highest surplus. Not submitting provides strictly more surplus than the other options if $0 > v^a q^r_{mt} - p^a$ and $0 > v^a - p^a - x^a$, which upon combining conditions yields

$$v^a < \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{D7}$$

Submitting under open access provides strictly more surplus than the other options if $v^a - p^a - x^a > 0$ and $v^a - p^a - x^a > v^a q^r_{mt} - p^a$, which upon combining conditions yields

$$v^a > \max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right). \tag{D8}$$

Because

$$\min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right) \leq p^a + x^a \leq \max\left(p^a + x^a, \frac{x^a}{1 - q^r_{mt}}\right),$$

it is immediate that the interval of author values is partitioned into three subintervals as shown in Figure D2, with no submission for the lowest values, submission under traditional access for intermediate values, and submission under open access for the highest values.

Zero, one, or two of the subintervals in Figure D2 can be empty in specific cases. There are seven ways this can happen, leading to the seven cases. The seven cases are detailed in Figure D3. The necessary and sufficient conditions are mutually exclusive and exhaustive. Which case to place the boundaries between them is somewhat arbitrary. We adopted the convention of setting the inequalities (strict or weak) such that a partition is displayed only if it contains a positive measure of types.

We will establish the necessary and sufficient conditions behind each case in Figure D3 in turn, starting with case (i). For there to be a positive measure of non-submitting authors,

$$0 < \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{D9}$$

But (D9) requires $p^a > 0$, implying

$$\frac{p^a}{q^r_{mt}} > 0. \tag{D10}$$

Next, for there to be a positive measure of authors submitting under traditional access,

$$\min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right) < \max\left(p^a + x^a, \frac{x^a}{1-q^r_{mt}}\right). \tag{D11}$$

For (D11) to hold, $x^a > 0$. Furthermore, one of the following two conditions must hold:

$$p^a + x^a > \frac{p^a}{q^r_{mt}} \tag{D12}$$

$$p^a + x^a < \frac{x^a}{1-q^r_{mt}}. \tag{D13}$$

Some algebra shows (D12) and (D13) are equivalent to each other and furthermore are both equivalent to

$$\frac{p^a}{q^r_{mt}} < \frac{x^a}{1-q^r_{mt}}. \tag{D14}$$

Condition (D12) implies that the cutoff between types who do not submit and types who submit under traditional access is $v^a = p^a/q^r_{mt}$. Condition (D13) implies that the cutoff between types who submit under traditional access and types who submit under open access is $v^a = x^a/(1-q^r_{mt})$. These simple expression for the boundaries are reflected in case (i) of Figure D3. Finally, for there to be a positive measure of authors submitting under open access, the boundary between traditional and open access must be strictly below $\bar{v}^a$:

$$\frac{p^a}{q^r_{mt}} < \bar{v}^a. \tag{D15}$$

Collecting conditions (D9), (D14), and (D15) yields the necessary and sufficient condition shown in case (i) of Figure D3.

Case (ii) can be analyzed using similar arguments maintaining the assumption $p^a = 0$. Turn therefore to case (iii). For there to be a zero measure of types submitting under traditional access,

$$\max\left(p^a + x^a, \frac{x^a}{1-q^r_{mt}}\right) \leq \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right). \tag{D16}$$

Condition (D16) implies

$$\max\left(p^a + x^a, \frac{x^a}{1-q^r_{mt}}\right) = \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right) = p^a + x^a. \tag{D17}$$

Hence the cutoff between types who do not submit and types who submit under open access is $v^a = p^a + x^a$. For there to be a positive measure of authors submitting under open access, this cutoff type must be strictly

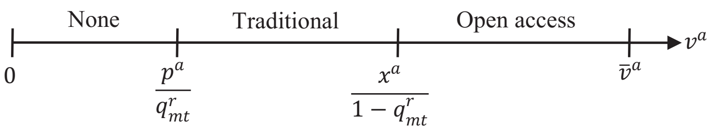
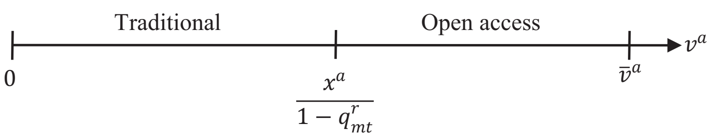
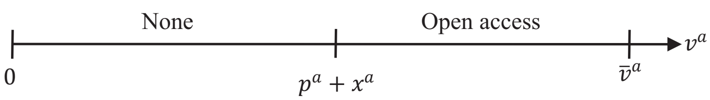
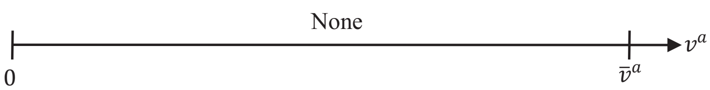
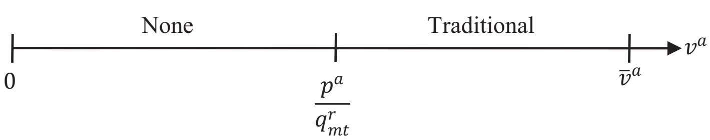
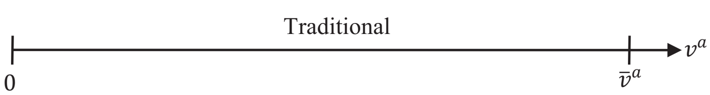
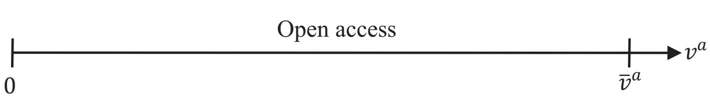
Case	Necessary and Sufficient Condition	Diagram of author submission strategy
(i)	$0 < \frac{p^a}{q^r_{mt}} < \frac{x^a}{1 - q^r_{mt}} < \bar{v}^a$	
(ii)	$0 = p^a < \frac{x^a}{1 - q^r_{mt}} < \bar{v}^a$	
(iii)	$\frac{x^a}{1 - q^r_{mt}} \leq p^a + x^a < \min\left(\frac{p^a}{q^r_{mt}}, \bar{v}^a\right)$	
(iv)	$\bar{v}^a \leq \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right)$	
(v)	$\frac{p^a}{q^r_{mt}} < \min(p^a + x^a, \bar{v}^a) \leq \frac{x^a}{1 - q^r_{mt}}$	
(vi)	$0 = p^a < \bar{v}^a \leq \frac{x^a}{1 - q^r_{mt}}$	
(vii)	$0 = p^a = x^a$	

Figure D3: Dividing author's equilibrium continuation strategy when facing a hybrid journal into detailed subcases. General characterization leads to seven cases depending on which partitions from the previous figure are empty.

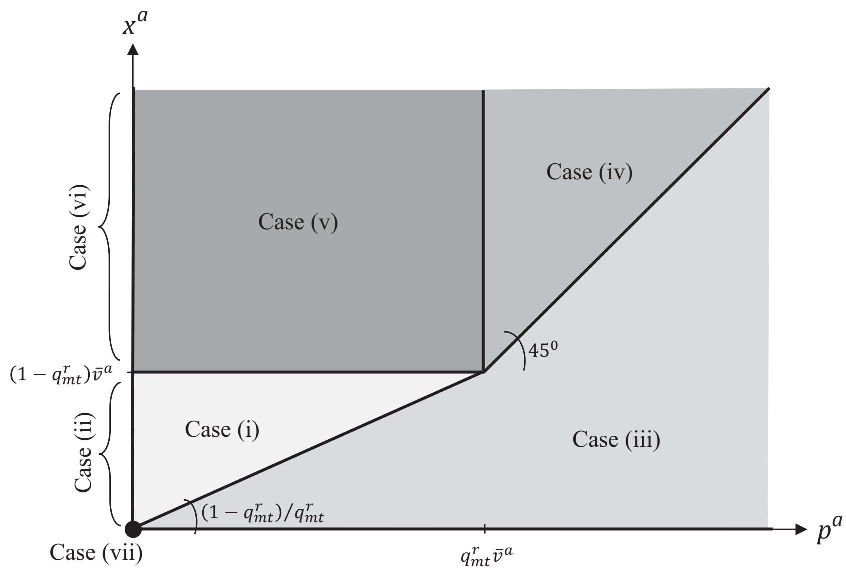


Figure D4: Graph of algebraic conditions from the previous figure. Cases along vertical axis involve zero submission fee: cases (ii) and (vi) are line segments and (vii) is a point.

below $\bar{v}^a$:

$$p^a + x^a < \bar{v}^a. \tag{D18}$$

The final step in deriving the necessary and sufficient condition for case (iii) in Figure D3 is to note that (D17) is equivalent to

$$\frac{x^a}{1-q^r_{mt}} \le p^a + x^a \le \frac{p^a}{q^r_{mt}}. \tag{D19}$$

Case (v) is analyzed similarly to case (iii). Case (vi) can then be analyzed using arguments similar to case (v), but maintaining the assumption $p^a = 0$. The details of these cases are omitted for brevity. This leaves cases (iv) and (vii). Consider each case in turn. For there to be a zero measure of submitting types (whether under traditional or open access),

$$\bar{v}^a \le \min\left(p^a + x^a, \frac{p^a}{q^r_{mt}}\right), \tag{D20}$$

the necessary and sufficient condition shown in case (iv) of Figure D3. For there to be a zero measure of both types who either do not submit or submit under traditional access,

$$\max\left(p^a + x^a, \frac{x^a}{1-q^r_{mt}}\right) \le 0, \tag{D21}$$

which is equivalent to $p^a = x^a = 0$, the indicated condition in case (vii) of Figure D3.

The algebraic conditions for the seven cases in Figure D3 are difficult to envision. Figure D4 graphs them in the price space for a hybrid journal, (p^a, x^a). The cases form four regions, two segments, and one point.

We next provide sufficient conditions under which equilibrium falls into the cases—(i) and (ii)—analyzed in the text. The first step is to restrict attention to the case in which a monopoly journal, if it were prevent from choosing a hybrid strategy and had to be either a purely traditional or purely open-access journal, would find the traditional strategy more profitable. Proposition 5 provided a sufficient condition for this outcome, and we will maintain that sufficient condition here. This rules out cases (iv), (v), and (vi) from

Figure D3 as possible equilibria. The next step is to provide a further condition under which a traditional journal would find it profitable to move to a hybrid model if it could. This rules out cases (iii) and (vii) from Figure D3 as possible equilibria, leaving cases (i) and (ii) as the only possibilities, as desired. We have the following proposition.

Proposition 15. *A profitable monopoly traditional journal would strictly profit from moving to hybrid pricing if $\bar{v}^a$ is high enough, a sufficient condition being*

$$\bar{v}^a > \frac{c^r + \pi^r_{mt}}{1 - q^r_{mt}}. \tag{D22}$$

Proof. Suppose a traditional journal currently charging author price p^a maintains that author price but adds the option of open access for a premium of $x^a = \pi^r_{mt} + c^r + \epsilon$ for some $\epsilon > 0$. For each author type who now chooses open access, the journal earns continuation profit

$$p^a + x^a - c^a - c^r = p^a - c^a + \pi^r_{mt} + \epsilon,$$

$\epsilon > 0$ more than it earned under the original traditional strategy. We need to check that a positive measure of author types choose open access. An author chooses open access if his benefit v^a satisfies $v^a - p^a - x^a > q^r_{mt} v^a - p^a$, or upon substituting for x^a and rearranging,

$$v^a > \frac{c^r + \pi^r_{mt} + \epsilon}{1 - q^r_{mt}}. \tag{D23}$$

But (D22) ensures that (D23) holds for some $\epsilon > 0$. □

The proof works by having the journal add an open access option, priced according to what in the context of telecommunications regulation is called the Efficient Components Pricing Rule (ECPR) (Baumol and Sidak 1994). To see this, consider the open-access premium for small ϵ:

$$\lim_{\epsilon \to 0} x^a = c^r + \pi^r_{mt} = (1 - q^r_{mt}) c^r + p^r_{mt} q^r_{mt}.$$

As specified by the ECPR, the open-access premium reflects two terms, a standard marginal cost term—in the present case the cost per reader c^r of serving the $1 - q^r_{mt}$ additional readers attracted by open access—and a second, opportunity cost term—in this case the lost revenue from these readers $p^r_{mt} q^r_{mt}$.

It remains to check that the sufficient conditions allowing us to focus on cases (i) and (ii) in equilibrium are not mutually inconsistent. This is easy to verify. We can ensure that hybrid pricing is more efficient than traditional by taking a distribution of author values with $\bar{v}^a = \infty$. Fixing this distribution and all other parameters, by Proposition 5 we can then ensure that a traditional journal is more profitable than an open-access journal by scaling the reader benefit as $\theta^r v^r$ and considering a sufficiently high value of θ^r.